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Institute for Mechanical Engineering

Annual Report 1991/1992

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Institute for Mechanical Engineering

Annual Report
1991/1992

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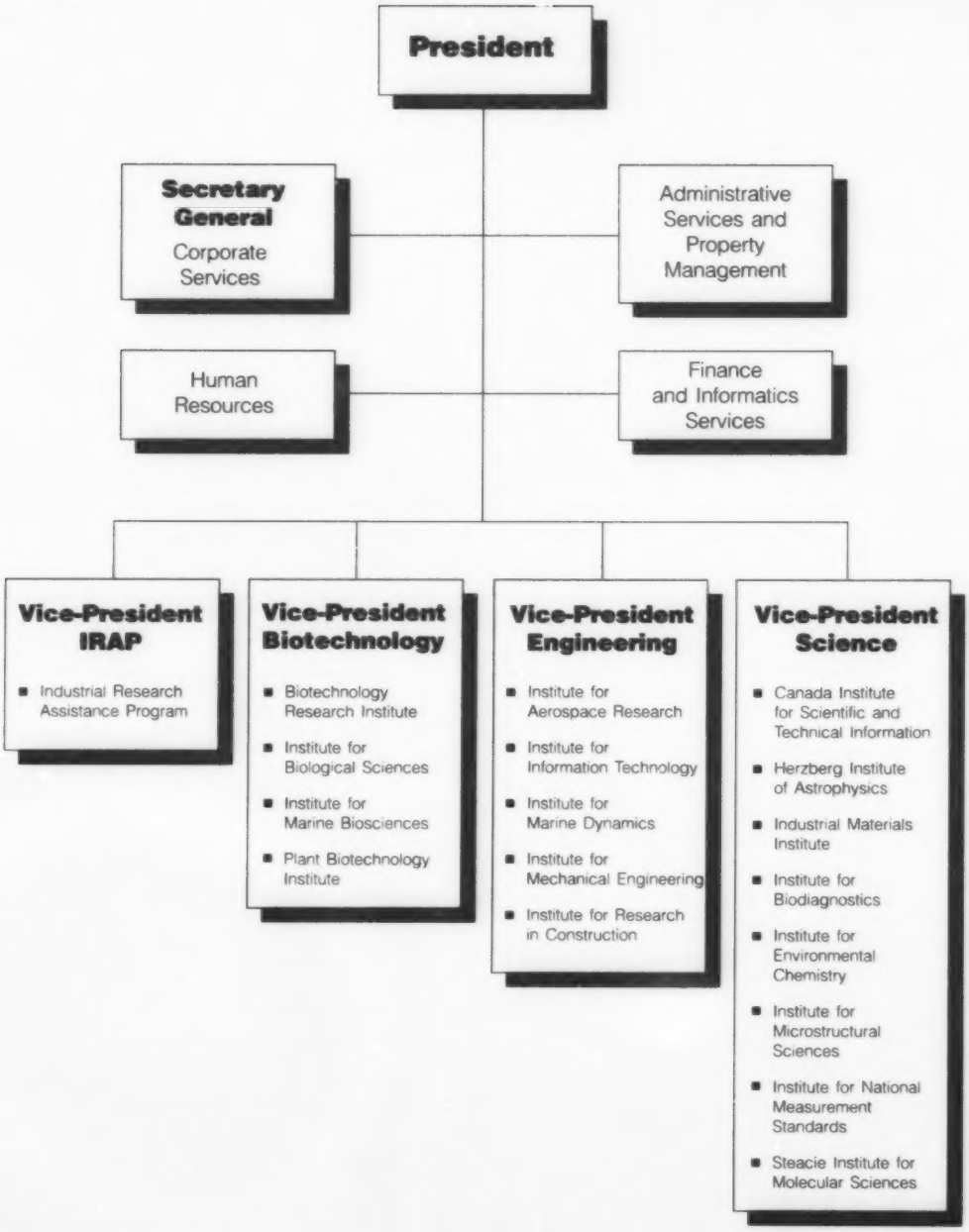
National Research Council Canada



1. Vice President's Message

Challenge and change. These are the watchwords of the nineties as Canadian companies strive to compete in the global marketplace.

Technology, the product of research and development programs, underpins industrial competitiveness. Therein lies our greatest challenge — to bring about advances in engineering, science, and technology that will help sustain the prosperity of Canada. The National Research Council is committed to collaborating with Canadian companies to achieve the technological advantage to compete and to succeed in the 1990s and beyond, as defined in the Long Range Plan.

The five institutes that form the Engineering Sector play a vital role to bring about the changes necessary throughout our society. The Engineering Sector serves Canada by promoting, practising, transferring, and disseminating engineering research, utilizing its unique facilities and expertise to improve the well-being of Canadians and enhance Canada's industrial competitive advantage. This year, the Engineering Sector faced some changes. The Industrial Research Assistance Program was separated from the Sector, and Dr. Clifford Baronet, Vice-President of Engineering and Technology, was asked to assume executive and operational responsibility for the program as Vice-President IRAP. I became Vice-President Engineering as of March 1, 1992.

A strategic assessment of NRC's five engineering institutes and three programs was initiated early in 1992. As a rigorous evaluation of NRC engineering R&D work and its impact, the study is helping to identify upcoming technological needs and opportunities in Canadian industry.

I wish to express my appreciation to Dr. Baronet for moving the Engineering Sector in this direction and for his contribution in defining the framework of the assessment. The findings of this comprehensive assessment study will help us align our research efforts to respond effectively to Canada's needs, especially in areas of wealth creation, the infrastructure, and the public good. This may well lead to some restructuring; we will face this challenge in the year to come.

In 1991, Institute Advisory Boards were established to involve the client community in our on-going strategic planning. The Advisory Boards, which have seen their first full year of operation, provide each institute with a window on the needs of its clients — and also provide the clients with a better appreciation of institute capabilities and resources. Thus the Advisory Boards, which are appointed by Council, help ensure that our research activities continue to be relevant to national needs and goals.

Other changes in the organization of the Sector occurred early in 1992. NRC's governing Council confirmed the establishment of the Institute for Biodiagnostics and the closure of the Canadian Institute for Industrial Technology in Winnipeg (CIIT). This resulted in a 3% decrease of the resources of the Engineering Sector.

Council also endorsed a proposal to establish an institute aimed at machinery research, in Vancouver. The personnel and financial resources of the Systems Laboratory (Institute for Information Technology) in Vancouver were transferred to the Institute for Mechanical Engineering as an interim measure, pending further development of the proposal for a new institute.

Enhancing the impact of our R&D work remains a primary concern and one of the most visible aspects of NRC's Long Range Plan. As outlined in the Sector's plans and priorities for 1991-92, we sought to increase our knowledge of the marketplace, strengthen our market orientation, and increase the awareness of NRC held by existing and potential clients.

Senior management, for example, conducted more than twenty executive briefings, which led to several new collaborative agreements. In total, forty-three new collaborative projects were signed and started in 1991-92.

In NRC's 75th Anniversary year, the many contributions of our staff members to the various special events were much appreciated. In particular, the Engineering Open House in October 1991 provided clients, stakeholders, colleagues, and the public excellent insight into the Sector's activities and the extent of our partnerships in research.

Income for the Sector has remained strong. In 1991-92, we reached 96% of our income target of $22M. Preliminary figures indicate that service revenue has decreased by about 10%. However, expenditures by our partners for work done by the Sector in joint research have increased. Royalties from licences have increased about 30%.

The Directors General and I have agreed that, in the coming year, our highest priority is to become more client-oriented. This means creating a "service culture" to improve the linkages between our R&D efforts and the needs of our many clients. It also means making our expertise and facilities more accessible to our clients. We know from recent studies that our clients already value the combination of advanced facilities and research expertise that we provide. We want to expand the number of new clients using more effective technology transfer mechanisms, as well as deepen our relationships with existing clients. In the meantime, we will continue to recognize and focus on "high leverage" opportunities; that is, opportunities for working with others, in projects where we can make a vital contribution.

This year will see the strengthening of the Engineering Sector Office. The Office will help co-ordinate affairs such as strategic planning, administrative and financial support, personnel services, and Sector communications. In addition, the Sector Office will continue to co-ordinate NRC programs in transportation, resources, and security.

Working together, we will maintain a program of world-class R&D. Engineering research and the development of technologies that pay dividends for Canada is our principal raison d'être. We must ensure that our partners in the private sector and elsewhere have access to the technologies resulting from our research activities and that they are able to use such technologies to Canada's competitive advantage. Only then will we have accomplished our goal.

More than ever, Canada needs the National Research Council. And, more than ever, the Council will rely on the talents of its employees. I look forward to working with all of you, as we meet the challenges of the future.

Joe Ploeg
Vice-President (Engineering)

2. Director General's Foreword

Dr. I.R.G. Lowe
Director General

IME pursued its mission very successfully.

NRC is dedicated to helping maintain and enhance the socio-economic well-being and the competitiveness of Canada. The Institute for Mechanical Engineering supports this mission by activities which are targeted at three vital sectors of the Canadian economy - transportation, resource industries and manufacturing. Within those sectors our R&D program addresses four areas of national concern; industrial international competitiveness, the environment, energy flexibility and national security including public safety.

During 1991-92 the Institute has pursued its mission very successfully. This was the first full year of operation after the restructuring of our research efforts into six programs and, as the balance of this report will show, our staff is to be congratulated for making this transition so effectively.

The IME Advisory Board was established and met twice, quickly taking an active role in shaping the strategic plans of the Institute.

IME took a leading role in the Engineering Open House to help celebrate the 75th Anniversary of NRC. Also in keeping with our Anniversary year, staff members participated in the NRC Public Lecture Series and presented the Canadian Society of Mechanical Engineering Student Lecture Series at 27 universities across Canada.

In keeping with Council goals and priorities, several collaborative research projects were initiated and renewed. Income from revenue work reached an all-time high and financial arrangements with other government departments were strong but dampened by the year-end spending freeze imposed by Treasury Board.

IME was host to nearly 100 guest workers and students, did business with over 200 clients, had formal and informal arrangements with more than 50 universities, 25 of them Canadian at which 12 of our staff held adjunct professorships. The Institute had linkages with several federal government departments, with provincial ministries and regulatory bodies, with standardization organizations in Canada and abroad as well as with other research organizations such as the Provincial Research Organizations.

Internationally, IME collaborated with laboratories and associations around the world. At the project level there was collaboration with each of the other Engineering Sector Institutes as well as with the Institute for Environmental Chemistry.

In the body of this report and in the Annexes is found overwhelming evidence of the technical success and relevance of our research programs. Much of our expertise is developed around our

National Facilities. Clients are attracted not only by the uniqueness of the facilities but by the expertise of our staff, and the clients provide a valuable window through which IME staff can glimpse incipient problem areas. A new, world-class, wave research flume for our Coastal Zone Engineering Program was completed this year and will be accepting clients by mid-1992.

Training was provided for staff through course attendance, both external and internal, through secondment and through educational leave. A move to staff more positions on a term basis was begun and will accelerate in 1992-93, with the intent that term staff will take their skills to Canadian industry when they terminate their employment with NRC.

In the coming year IME plans to add three Research Associates, four new Visiting Researchers, one additional Research Fellow, one student under the *Women in Science and Engineering Program* and two candidates under the proposed *NRC Technical Associates Program*. Management training for the research staff was instituted on a broad basis and will continue in the coming year.

IME's six research programs are truly relevant to Canada's socio-economic well being.

IME is developing a proposal for an Engineering Sector Institute in Vancouver to be focused on machinery as related primarily to the resource and transportation sectors. This initiative was given approval-in-principle by Council late in fiscal year 1991-92. Should it receive final approval late in 1992, for initiation in early 1993, it will impact the resource base of IME as it will involve the transfer of parts of our Machinery and Engine Technology Program.

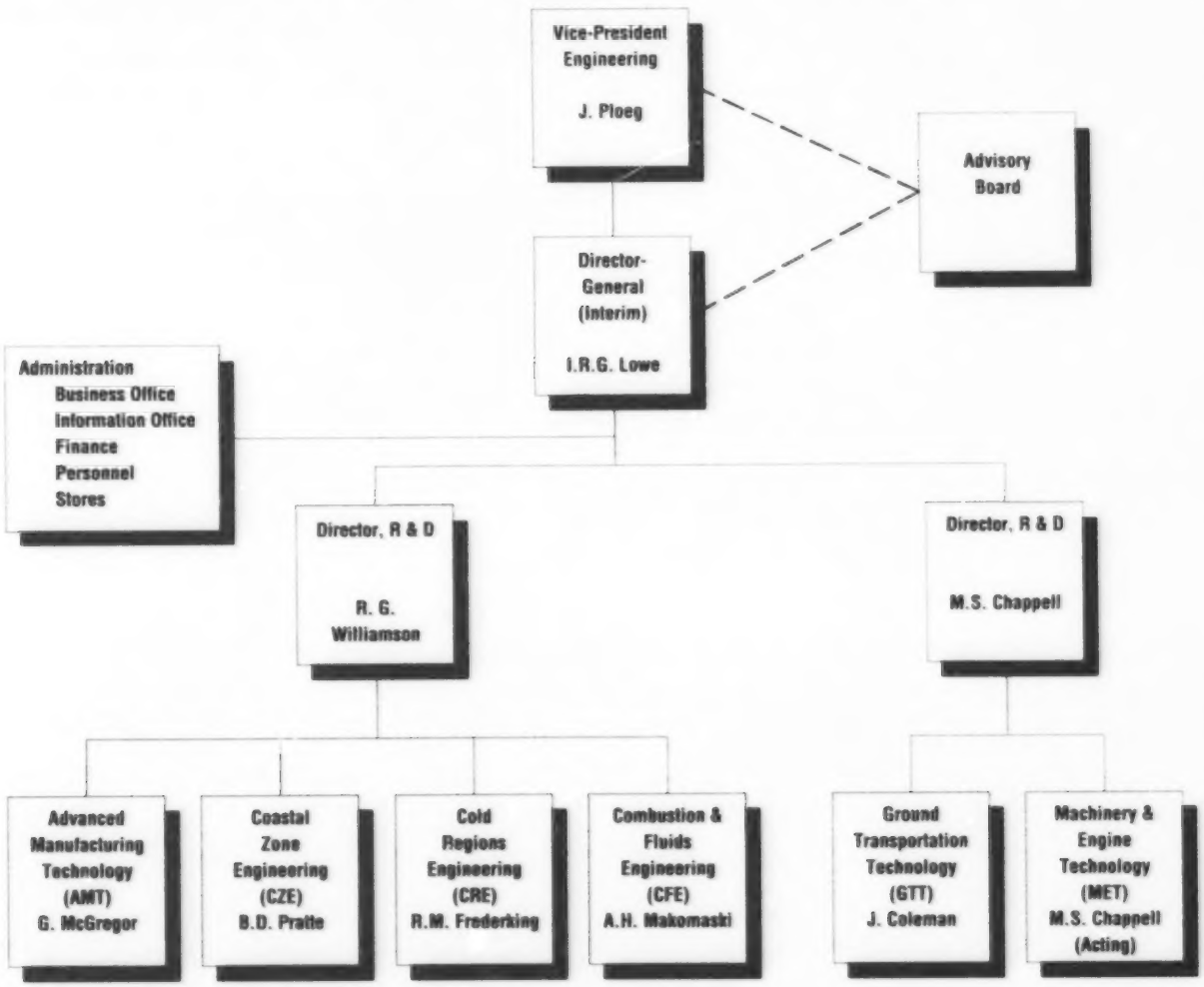
Another proposal under Council consideration is an *Institute for Advanced Manufacturing*. Again, its establishment would undoubtedly involve resources from our Advanced Manufacturing Technology Program as well as from other NRC Institutes.

As part of an Engineering Sector restructuring some staff and equipment from the *Canadian Institute for Industrial Technology* in Winnipeg will join IME in Ottawa as the new *Institute for Biodiagnostics* in Winnipeg gets established. As well, staff of the *Institute for Information Technology* who are located in Vancouver will become part of IME at the beginning of 1992-93.

An assessment of the Engineering Sector was begun late in 1991-92 and will be completed in September 1992. This will lead to a new strategic plan for the Sector with probable implementation in 1993. IME is confident that its six research programs, which are described in the body of this report, are truly relevant to Canada's socio-economic well being, especially in today's economic climate. Any strategic plan developed as a result of the assessment should include these vital elements.

3. Institute Organization

IME is one of five Institutes which make up the Engineering Sector, the responsibility of the Vice-President Engineering. The Institute organization chart presented below came into effect on 1 March 1992 when Mr. J. Ploeg, formerly Director General of IME, became Vice-President Engineering. The Director General is now aided by two Directors of Research with responsibility for six research programs which are described in Section 4. The Director General is also supported by an administrative group as shown.



4. 1991-92 Institute Activities

4.1 Institute Goals and Achievements

The Institute for Mechanical Engineering (IME) is committed to the mission of the National Research Council of Canada which is to serve the needs of Canadians by helping to maintain and enhance the economic and social well-being of the country.

> *"The mission of IME is to improve Canada's productivity, competitiveness and environmental and social well-being by undertaking, supporting, promoting and disseminating research and development in the mechanical engineering aspects of three vital sectors of the Canadian economy - transportation, resource industries and manufacturing."*

Within those three sectors the R&D program also addresses four issues of national concern:

- industrial international competitiveness
- the environment
- energy flexibility
- national security

The Institute achieves its mission by:

- performing research and development.
- developing, providing and transferring expertise and knowledge.
- establishing and operating major engineering research facilities, and making them available to collaborators and clients.
- undertaking international liaison and collaborative research activities to acquire global expertise, and to maintain a Canadian presence in world research.

The objectives of IME's Programs of research are specifically aimed at supporting in Canada:

- improvement of vehicles, propulsion systems and transportation related facilities and services
- improvements in the design and operation of maritime structures and other coastal engineering works
- protection of the environment
- enhancement of energy flexibility
- advancement of firms engaged in manufacturing and resource extraction
- related programs of other government departments and agencies

The effectiveness of the program is assessed on the basis of the quality and relevance of the research activities and related initiatives, and by the degree of satisfaction expressed by collaborators and clients.

As mentioned in Section 2, the restructuring of research activities into six programs, synonymous with sections, was accomplished very successfully and no major changes were found to be necessary during the course of the year. On the other hand, a stable but non-growing resource base precluded major new initiatives within the research program.

The revenue target for 1991-92 set at $1.8M was exceeded by close to $0.4M despite the economic downturn in Canada. Forecast income for next year is cautiously optimistic because of predictions of a slow recovery from the recession.
The resources required to maintain and upgrade our extensive National Facilities remain a concern. Initiated in 1990-91, funding of close to $1M in total by the end of 1991-92 allowed the completion of the

new Wave Research Flume on time and on budget. Health and safety enhancements to buildings M-10 (CFE) and M-7 (MET) were initiated and should be completed in 1992-93.

The Institute Advisory Board, whose activities are described more fully in Section 7, met twice in 1991-92. The members expressed their approval of the R&D program as now structured and provided valuable guidance to the Institute long-term, strategic planning process.

4.2 Summary of Research Programs & Activities

The Institute for Mechanical Engineering comprises six Research Programs:

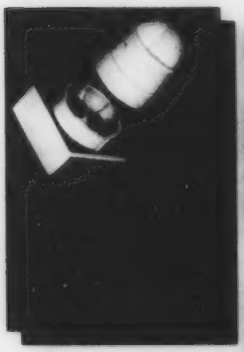
- Advanced Manufacturing Technology (AMT)
- Coastal Zone Engineering (CZE)
- Cold Regions Engineering (CRE)
- Combustion and Fluids Engineering (CFE)
- Ground Transportation Technology (GTT)
- Machinery and Engine Technology (MET)

The rationale and major research thrusts of each Program are described below. Annex I contains specific achievements in 1991-92.

4.2.1 Advanced Manufacturing Technology Program (AMT)

The Program addresses the industrial competitiveness of Canada's large manufacturing sector. Manufacturing has become the largest and most important sector of the Canadian economy, accounting for just over 25% of the GDP. Close to 2.5 million people are now employed in over 50,000 manufacturing companies in Canada, and approximately one-third of the total Canadian population is supported by the manufacturing industry. The need for a strong base in manufacturing R&D is even more apparent when it is recognized that more than 50% of industrial R&D in manufacturing technology is done by only 25 companies (0.05%!). It is only through the introduction and effective use of new technologies and processes that Canadian firms can compete successfully internationally.

Rapid Prototyping: From 3-D CAD image to a plastic prototype overnight, using laser stereolithography.



Surface reformation: Creating tungsten carbide edges on metal and wood cutting tools using a proprietory laser cladding process.

50% of industrial R&D in manufacturing technology in Canada is done by only 25 (0.05%) companies!

IME's AMT Program is designed to address these needs, with the following three Subprograms:

- New Manufacturing Processes: materials processing by lasers (e.g., the modification of material properties to enhance product performance); machining of and with advanced materials (e.g., metal matrix composites for the automobile and aerospace industries); and computer aided near net shape processes (e.g., methodologies for reducing the cost of fabricating dies, patterns and molds).
- Manufacturing Systems: integration methods for NC machine tools and precision verification and enhancement for prototype shapes.
- Design and Fabrication: projects involving the design and development of machines and systems, primarily for other NRC laboratories.

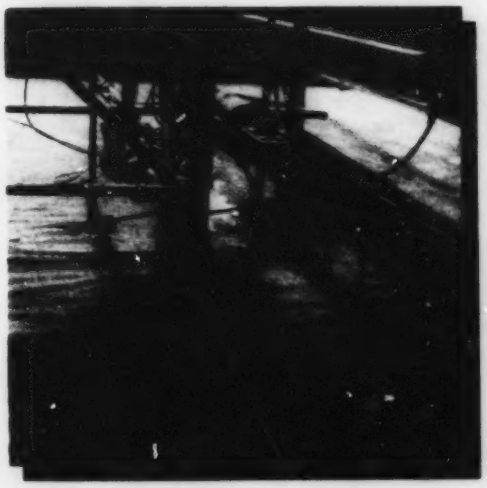
4.2.2 Coastal Zone Engineering Program (CZE)

The CZE Program is carried out in NRC's Hydraulics Laboratory, Canada's largest laboratory for coastal engineering research and development. Canada has one of the world's longest coastlines, and a $60B coastal infrastructure. Over $1B per year is spent in Canada on development of small fishing ports and marinas, major harbours, recreational and shoreline projects, river and estuary problems, and on oil exploration and production structures in the coastal zone. It is important that coastal engineers in government and in private industry have access to the largest, most advanced facilities and expertise, to evaluate and refine their design concepts, and to arrive at the safest, most cost-effective structures. Over the next 50 to 75 years, the mean sea level is expected to rise by up to one metre, flooding low-lying areas and allowing waves to attack erodible bluffs currently protecting the coasts. To deal with these severe effects, engineers must develop technologies, such as techniques for raising existing structures and/or building new ones able to cope with a rising sea level.

Canada has the longest coastline in the world.

The CZE Program comprises the following four Subprograms:

- Physical, Numerical and Hybrid Modelling of Coastal Engineering Processes.
- Modelling Civil Engineering Structures in the Coastal Zone.
- Physical and Numerical Modelling of Wave Generation and Absorption in Wave Basins.
- Enhancements to GEDAP (Generalized Experiment control, Data acquisition and Analysis Package) in Support of Laboratory Testing.



Instrumentation array measuring velocities and suspended sediment over sandbed ripples in multidirectional waves to predict erosion/deposion.

Instrumented rock armour layer of breakwater to determine waves with greatest damage potential.

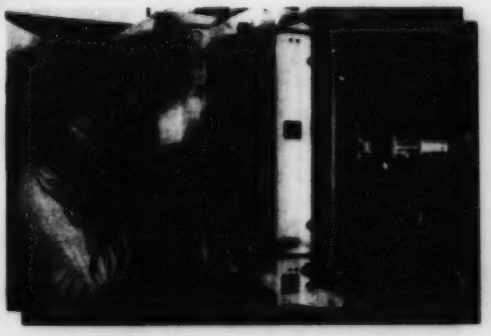
4.2.3 Cold Regions Engineering Program (CRE)

The CRE Program addresses Canadian priorities for environmental protection and for competitive industrial operations in a cold climate. The Montreal Protocol bans CFCs by 1997 in Canada, necessitating development of new, environmentally acceptable refrigerants. More efficient thermal systems are needed to reduce energy consumption and simultaneously to limit waste heat discharge to help counteract the effects of global warming.

Safe, cost-effective and environmentally acceptable equipment is vital for responsible exploitation of Arctic and off-shore resources. CRE's expertise and facilities contribute significantly to Canadian solutions to these Canadian conditions. The CRE Program comprises six Subprograms grouped into two areas, viz:

Climatic Engineering

- Ice Mechanics: characterization of ice properties and prediction of ice forces on structures.



Icing Tunnel being used to improve the icing detection capability of an aircraft-mounted instrument which warns the flight crew of potentially hazardous icing conditions.

- Environmental and Climatic Research: technology for protection of vehicles and structures from snow and icing conditions.

- Industrial Equipment Climatic Evaluation: assessment and improvement of operation of equipment under severe climatic conditions.

Advanced Thermodynamics & Heat Transfer

Alternative Refrigerants Test Facility being used for evaluating system performance of new environmentally-friendly refrigerants.

- Alternative Refrigerants & Heat Pumps: addresses national concerns for environment and energy security through development and application of new (non-CFC) refrigerants, and advanced heat pump development.

- Advanced Heat Transmission Fluids: improves efficiency through use of non-conventional thermal energy carriers such as ice slurries.

- Computational Fluid Dynamics: develops analytical techniques to predict fluid flow and heat transfer performance.

Potential of even minor improvements in thermodynamic process efficiencies will result in a significant return on investment.

4.2.4 Combustion and Fluids Engineering Program (CFE)

The Program addresses the issues of the environment, energy flexibility and national security. An improved understanding of combustion and related fluid flow processes is urgently needed to enhance overall energy flexibility, reduce local and global pollution due to harmful emissions and permit the introduction of alternative fuels and propulsion systems. Annual sales of natural gas and liquid petroleum fuels in Canada exceed $35 Billion. The potential of apparently minor improvements in thermodynamic process efficiencies to provide a large return on investment in energy, and result in direct reduction of emissions and a saving of non-renewable resources, is immense.

The seven Subprograms which make up the CFE Program are as follows:

- Strategic Combustion Research: Typical areas include turbulent pre-mixed combustion, turbulent diffusion combustion, liquid spray dynamics, liquid spray combustion, flow/spray visualization, soot/particulate formation and combustion diagnostics.

- Fuel Technology: The research activities include characterization of liquid fuels, correlation of composition with combustion performance, ignition quality and emissions, as well as alternative fuels.

- Applied Combustion R&D: This work provides the essential link between the expertise and experimental results from the other combustion Subprograms and the industrial development of fuel injection systems, gas turbine combustors, reciprocating engines and industrial furnaces.

- Fluid Dynamics: This activity covers a broad range of fundamental phenomena including work in transonic aerodynamics, turbulent mixing, and boundary layer diagnostics, with applications in turbomachinery, industrial processes and medical technology.

- High Speed Water Jets: This Subprogram addresses specialized areas of fluid dynamics (such as cavitation and pulsatile flows) which are important in the cutting processes using high speed water jets.

Dynamics of Pool Fires
To enhance safety, the CFE Program is studying ways of increasing the luminosity of methanol fuel flames.

4.2.5 Ground Transportation Technology Program (GTT)

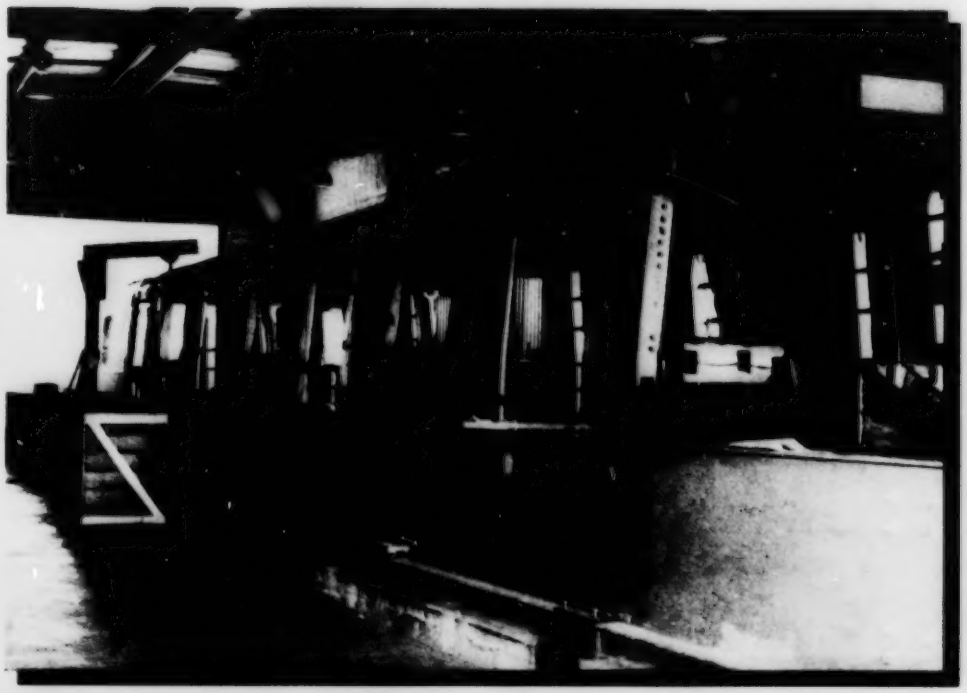
The GTT Program reflects the vital importance of ground transportation to the economic and social well-being of our vast and resource-rich country. Currently, transportation comprises 30% to 50% of the market cost of Canadian raw materials. The increasing proportion of heavy freight being carried on Canadian roads is exacerbating the damage to the existing infrastructure. Recent studies have shown that an immediate expenditure of $12B is required to rehabilitate existing Canadian highways, and that this deficit increases by about $1.5B annually because expenditures for repairs are significantly less than the $8B/year required. The majority of road infrastructure damage is known to be caused by heavy trucks. Better understanding of the dynamic interactions between heavy truck suspensions and the pavement substructure is essential for maximizing the cost-effectiveness of road repair procedures and for the design of better and safer vehicles.

Transportation is paramount to the Canadian economy

- Computational Fluid Dynamics: The development, evaluation and application of appropriate computational techniques for the prediction of phenomena in combustion and fluid flow processes are key elements of this Subprogram.

- National Facilities: The work in this Subprogram covers the operation and maintenance of the large Compressor/ Exhauster Plant, the Engine Altitude Experimental Facility, the Propulsion Wind Tunnel and the High Pressure Steam Plant. Virtually all R&D using these national facilities is conducted with or for Canadian industry and OGD's.

Railway freight productivity and safety are continuing priority areas within the GTT Program. Over 40% of Canadian freight tonnage is transported by rail, particularly bulk resource commodities such as coal, wheat, potash, etc. Trends to ever-larger freight cars, with even higher axle loadings have serious ramifications on operating safety, stability and track deterioration. The GTT Program is the Canadian source of technical understanding of these phenomena, and the research is performed in close collaboration with Canadian railways and the Association of American Railroads. Emerging interest by major Canadian industries in high-speed passenger rail systems for North American applications requires that the GTT Program extend its expertise into this new technology.



The prototype body shell of a subway car designed and built by Bombardier Inc. for the New York City Transit Authority is undergoing structural strength certification tests. The car is shown in IME's Squeeze Frame. Stresses and strains were measured at over 300 points simultaneously on the car body when subjected to longitudinal compressive forces, to determine whether the car structure would permanently deform. Successful completion of the tests represented a milestone under the contract which was valued at $19.5 million.

Semi-trailers forming part of a novel intermodal railway/highway system under test. The system includes a new design of railway bogie for carrying trailers by rail without using flat cars; it is shown being "characterized" in terms of stiffness parameters using IME's vehicle dynamics facilities. This is an essential step in assessing whether the design is prone to derailment and needs modification. Also forming part of the system is a new design of motive power unit (not shown). The Canadian developers have recently teamed up with CN Rail to refine and implement the system.

The GTT Program comprises three Subprograms, viz:

- Railway Vehicle R&D: focuses on complex dynamic interactions between the vehicle, its suspension components and the track, including the tribology and metallurgy of the critical wheel/rail contact area.
- Highway Vehicle R&D: focuses on the stability and controllability of single and articulated highway trucks and their dynamic interactions with the road surface.
- National Facilities: are required for experimental research on full scale equipment to validate analytical prediction methods, and to aid manufacturers in certification of new designs.

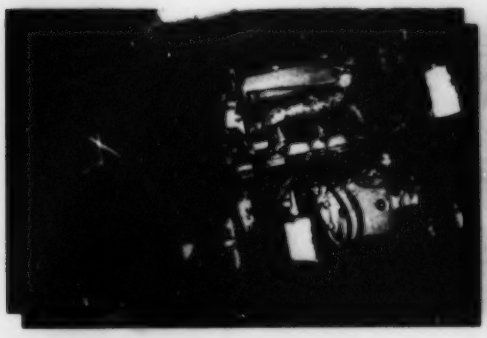
4.2.6 Machinery and Engine Technology Program (MET)

The MET Program reflects the immense Canadian investment in machinery and engines, particularly in the resource and manufacturing sectors, and in both civilian and military transportation sectors. The capital cost of the CF-18 fleet alone is $4.5B. The MET Program focuses on technology for safe, efficient performance of engines and machinery and their condition monitoring. More efficient Canadian-built engines contribute to energy self-sufficiency and to environmental protection, while simultaneously improving the competitive position of Canadian manufacturers and users. Machinery and engine condition monitoring improves industrial operations by increasing safety and reliability, and by reducing maintenance costs. The potential saving from condition monitoring of diesel engines has been estimated at $300M/ year. A recent study by the Associate Committee on Tribology states *"Canada loses more than $5 billion annually due to friction and wear ... about $1.3 billion, or some 25% of these losses, could be saved through better application of existing technology and through research and development."*

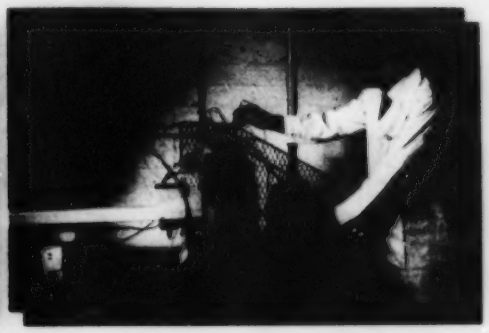
The MET Program comprises ten interrelated Subprograms grouped into three areas, viz:

Engine Technology

- Gas Turbine Performance Assessment: advanced techniques for accurate determination of steady-state and transient engine performance in test cells and installed in aircraft.
- Turbine Engine Operations: including development and verification of engine condition diagnostic software, certification of engines for flight in adverse weather conditions, and assessment of strategic fuels for military operations.
- Turbomachinery Aerothermodynamics: research towards improvements in efficiency and cost-effectiveness of highly loaded small aspect ratio turbine stages appropriate to Canada's world-leading small gas turbine industry; development of techniques to assess aerodynamic performance of intakes and compressors, including advances in non-intrusive instrumentation essential for small engines.



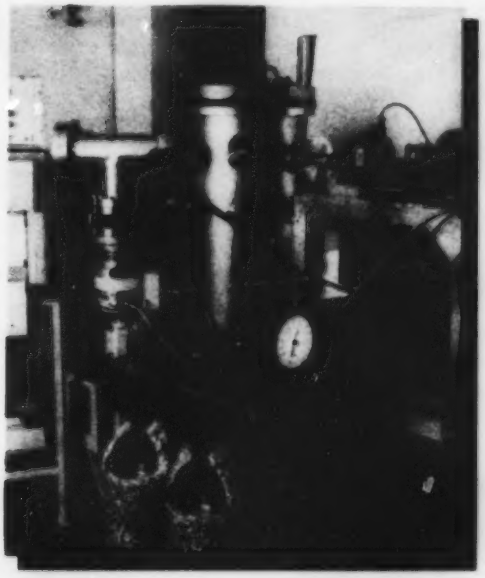
Development of a novel instrument for measuring diesel engine performance based on crankshaft speed fluctuations.



Test rig for on-line debris monitoring of bearings.

Machinery Diagnostics

- Vibration and Acoustic Analysis: to detect and identify deterioration and incipient malfunctions in machinery and propulsion systems, including non-uniform performance among cylinders of industrial diesel engines.
- Debris Monitoring: to detect and identify the source of minute particles shed by deteriorating components into the oil and gas streams of engines and other types of machinery.



High vacuum tribometer for investigating the wear and friction of materials suitable for extended use in space mechanisms, such as joint brakes on the Space Shuttle Remote Manipulator System.

Tribology & Mechanics

- Fluid Film Lubrication: research on hydrodynamic bearings and systems, and on industrial applications of these bearings for the transportation, resource processing and electrical utility sectors.
- Friction and Wear: studies of metallic and non-metallic materials under continuous, oscillating and impacting loads in terrestrial and space applications.
- Rolling Contact Tribology: focuses on the tribological phenomena governing rolling contact situations such as the railway wheel/rail interface.
- Rotor Dynamics: studies of means to reduce the excitation of machinery vibrations through improved rotor balancing and machinery unbalance response analyses.
- Mechanism Synthesis: development of novel mechanical equipment for more sustainable methods of forestry and agriculture.

4.3 Partnerships and Services

4.3.1 Advanced Manufacturing Program

A key collaboration is with the University of British Columbia on open architecture controllers. The adaptive attributes of open architectural controllers to rapidly process feed-back information may very well open up new avenues for the application of the laser machining and surface modification processes. Since the work is of international scope it brings up the issue of off-shore marketing, sales and collaborations.

In general, the weak manufacturing infrastructure in Canada, coupled with historical ties to the US market, makes it difficult to find Canadian partners who are capable of running with world class developments. The special purpose machine for Clynch Prosthetic Orthotic Laboratory Ltd. is an example of where more time was spent in creating partnerships, linkages and financing than on the actual research and development. Some other important developments have not been as fortunate. An attempt to create the climate for the production, development and marketing of an important breakthrough in laser technology resulted in so much frustration that the inventor ultimately sold the rights to German laser interests. Such experiences suggest the need for strategically located application development centres linked to financial and business development organizations, which would help nurture important developments, which characteristically seem to attract small or start-up companies.

4.3.2 Coastal Zone Engineering Program

CZE has important collaborations with Canadian firms marketing wave generator and controls technology (W.R. Davis Engineering Ltd.), GEDAP software (Dominis Engineering Ltd.), and passive wave absorbers (Dramex Ltd.) This has been very effective and has resulted in the sale of almost $20M of wave generators, control systems, and GEDAP software around the world.

Arising from the phasing-out of the NRC Associate Committee on Shorelines, CZE has been instrumental in creating the Canadian Coastal Science and Engineering Association (CCSEA), a private, not-for-profit association. CCSEA brings together scientists working in the coastal zone through conferences and workshops, and in collaborative field studies. CCSEA is a valuable source of advice on the direction of the CZE Program, ensuring it is relevant to the needs of the coastal engineering community.

Collaborations continue on wave generation in lab basins with national and international agencies including the University of British Columbia, Queen's University, University of Delaware, University of Grenoble, University of Cantabria, Danish Hydraulic Institute, and the Port and Harbour Research Institute of Japan.

4.3.3 Cold Regions Engineering Program

The partnership with CANMET (EMR) and Sunwell Engineering on the application of ice slurries in district cooling systems has continued and expanded to include McGill University.

The ongoing joint research project on alternate refrigerants with DuPont Canada and EMR remains a key element in our Program and will be broadened to include Environment Canada.

Drs. R.M.W. Frederking and G.W. Timco hold adjunct professorships at Memorial University, St. Johns, as well as Dr. N.K. Sinha at the University of Ottawa.

4.3.4 Combustion and Fluids Engineering Program

Research and development activities of this Program are supported by the Department of National Defence, Energy, Mines and Resources Canada, and Transport Canada. In addition, work is also carried out for the Transportation Safety Board of Canada.

The Transportation Energy Division of EMR is supporting a cost-shared project of research in combustion as part of Canada's participation in the International Energy Agency's Agreement on Energy Conservation in Combustion.

A major collaborative project is under way with HDRK Mining Research Limited. This is a feasibility study of pre-weakening rocks with novel water jet techniques for mining applications.

In 1992-93, new collaborative ventures are expected to include turbine blade research with Pratt and Whitney Canada and research and development of a high intensity industrial burner with Conamara Limited.

Although conducted on the basis of fee-for-service, the work with Westinghouse Canada is a research partnership aimed at development of a dry low-NO_x combustion system for the industrial gas turbine market worldwide.

Researchers in the Program maintain close contacts and collaborations with a number of universities including Queen's University, Carleton University, Colorado School of Mines, University of British Columbia, and the University of Ottawa.

4.3.5 Ground Transportation Technology Program

The Railway Truck Characterization and Modelling project depends on the continuing collaboration of CP Rail (Research and Development). To date this has included sharing of extensive field data, extended loan to NRC of a freight car with a range of interchangeable wear-prone truck components, and engineering supervision of experimental work at NRC.

The Truck Pedestal Components collaborative project, while still tentative, has received approval-in-principle from CP Rail (Mechanical Division), CN Rail (Mechanical and Electrical Division), and American Steel Foundries.

The Heavy Vehicle Performance Measures project will require the collaboration of one or more large provincial ministries of transport, one or more large truck fleet owners, and perhaps the Canadian Trucking Association. A detailed workplan is pending. Respective roles and responsibilities are to be determined, but NRC anticipates conducting the computer modelling and analysis while the collaborators conduct analysis and surveys of truck fleets. The ministries of transportation of Ontario and Saskatchewan have expressed preliminary interest.

The Ground Transportation Technology Program also depends on collaboration with two principal industry associations for assistance in intelligence gathering, identifying priorities, crystallizing and vetting new project concepts, organizing of collaborators and user communities, and disseminating technical results. The Transportation Association of Canada (TAC) fulfils this role for GTT's highway activities, and a close and symbiotic collaboration has been developed since 1982. TAC represents the interests of the large majority of GTT's constituent community.

The Association of American Railroads (AAR) holds promise for fulfilling this role in a comparable way for GTT's railway activities. Initiatives are underway to link GTT with the AAR in committee memberships, joint project planning, workload sharing, exchange and critiquing of results, and reciprocal use of facilities. AAR represents the interests of North America's railway industry, including the main Canadian firms.

4.3.6 Machinery and Engine Technology Program

Key partnerships and collaborations are with Pratt & Whitney Canada (PWC) and with a number of directorates within the Department of National Defence (DND). PWC, Canada's world-leading designer and manufacturer of small gas turbines, undertakes substantial product-oriented R&D itself, but collaborates with NRC for much of the more fundamental, longer-term turbomachinery research.

The Department of National Defence supplies this Program with a large cash resource, multi-million dollar engines, direct access to Canadian industries, and a collaboration with other international research agencies and industries through The Technical Cooperation Programme (TTCP) and the NATO Advisory Group for Aerospace Research and Development (AGARD). Direct linkages have been established with international research performers who have shared their data, methodologies and professional expertise through an exchange of personnel.

Other Canadian organizations with which this Program collaborates include:

- Standard Aero Limited
- GasTOPS
- Carleton University
- Queen's University
- Davis Engineering
- Laval University
- SPAR Aerospace
- École Polytechnique
- B.C. Skytrain
- General Motors Ltd.
- Loram Ltd.
- Advanced Rail Management Ltd.
- Alberta Research Council
- PAPRICAN
- Domtar
- General Electric Canada, Inc.
- Kingsbury, Inc.
- Pratt and Whitney Canada
- Ontario Hydro
- B.C. Association for Regenerative Agriculture
- B.C. Ministry of Agriculture
- University of Victoria
- B.C. Science Council
- McMillan Bloedel
- Interpro Ltd.
- Suncor Ltd.
- Polytechnical University of Torino (Italy)
- University of Ottawa
- Unique Mobility (USA)

4.4 International Activities

The target clientele for the Advanced Manufacturing Technology Program is the Canadian manufacturing industries, so there is little international activity beyond maintaining awareness of materials and techniques being developed in other countries.

In the Coastal Zone Engineering Program there is collaboration in development of a 3D version of NPMPROG, a numerical package from Hydraulics Research Ltd. and Sir William Halcrow and Partners (all of the UK). NPMPROG will permit prediction of sediment movement along beaches and coastlines, beach profiles, deposition and erosion, and conditions near harbours. CZE also collaborates with the Danish Hydraulic Institute in further development of their System21 and Mike21 hydronumerical packages to model the action of waves and currents moving into harbours or along the coast.

In the Cold Regions Engineering Program information exchange with French researchers at Université de Nancy, GRETL Lab, and Electricité de France on new refrigerants considerably enhances our alternate refrigerants project. Participation in International Energy Agency activities continues to provide the program with a window into international R&D activities on heat pumps and alternate refrigerants as well as a point for developing strategic linkages with foreign research institutes. These linkages are also used to bring in visiting researchers from overseas to assist in carrying out research on alternate refrigerants and ice slurries.

A CRE joint research project with Helsinki University of Technology on ship interaction with complex ice was completed this year, but efforts are being made to define a follow-on project. A new joint research project with the Technical Research Centre of Finland and NRC's Institute for Marine Dynamics will continue for three years. It will study propeller/ice interactions. A long term joint research project with IME and the Hamburg Ship Model Basin on modelling realistic ice conditions will be initiated. These projects keep CRE in close contact with ice research in Finland, Germany and IMD.

The Combustion and Fluids Engineering Program has strong ties with international research organizations through engineering societies such as ASME, SAE, CASI, through NATO R&D organizations such as AGARD, and through the International Energy Agency. Valuable collaborative information exchanges on combustion diagnostics continue with Wright-Patterson Air Force Base in the USA.

The CFE High Speed Water Jets Subprogram has international contacts and obligations as represented, in particular, by the International Society of Water Jet Technology and the International Journal of Water Jet Technology.

On the road freight side of the Ground Transportation Technology Program, significant interactions take place with a variety of American transport authorities to ensure a common technical basis for trucking regulations. The GTT Suspension Vertical Dynamics and Loading of Pavements project depends on the continuing collaboration of the 13 other principal road research laboratories already participating (including Australia, France, Germany, the U.K. and the U.S.A.) Within Canada, subsequent phases of the project will depend on the collaboration of one or more provincial ministries of transportation (Québec has expressed preliminary interest). There is also a strong linkage with the Geotechnical Section of the Institute for Research in Construction.

Related to rail freight, initiatives are underway to link GTT with the Association of American Railroads in technical committees, joint project planning, workload sharing, exchange and critiquing of results and reciprocal use of specialized facilities.

International collaborations and joint research activities are a major feature of the Machinery and Engine Technology Program. These arrangements provide access to data and expertise that contributes directly to program objectives. Current co-operation activities are underway with:

- DLR Köln (Germany) - L2F flow measurement technology
- Wright-Patterson Air Force Base (USA) - model comparisons, DSTI
- NAPC, AEDC (USA) - collaborations via MDEA
- DSE Pyestock (UK), DSTO-ARL (Australia), NASA LeRC (USA) - sensors
- NAPC (USA), DSTO-ARL (Australia) - real time thrust sensor system
- NATO Advisory Group for Aerospace Research and Development (AGARD) (Participation in working groups for writing common reports, holding symposia for information exchange and consultants program for lectures and training)
- The Technical Cooperation Program (TTCP): (collaborate in 6 technical areas, write evaluation reports, and hold workshops)
- SAE Aerospace (International)
- Master Data Exchange Arrangement (MDEA): USAF, USN, and NRC - (for collaborative projects on sensors and data comparison methods)
- International Standards Organization (machinery sound intensity measurement techniques; in-flight aircraft interior noise measurement techniques)
- International Electrotechnical Commission (instrumentation to measure sound intensity - NRC techniques are being adopted internationally)
- ANSI (determination of sound power of noise sources; instruments to measure sound intensity)
- Acoustical Society of America (determination future ASA research priorities)
- NASA Lewis Research Center (vibration characteristics of healthy and faulty gears)
- Burlington Northern Railroad (performance monitoring of locomotive diesel engines)
- Cambridge University, UK (Collaborative studies on the mechanics of rolling contacts)
- INSA laboratoire de mécanique des contacts, Lyon, France (Collaborative research on wear and friction modelling)
- VAMAS Wear Task Group (International collaboration on standard wear test method development)
- International Tribology Council (Institute should become Canadian representative on this international coordinating body)
- OECD Research Group on Wear of Engineering Materials (Forum for discussion of wear)
- ROMAC, University of Virginia, USA (Liaison regarding the dynamic performance of fluid film bearings)
- Rensselaer Polytechnic Inst. Troy, N.Y. (Collaboration in full scale study of vertical bearings)
- Korean Standards Research Institute (Collaborative development of super-critical rotor balancing method)

5. Management & Administration

5.1 Organization

The IME management "team" consists of the Director General, two Directors and six Program Heads. They are supported by the Administration group which comprises the Business Office, Information Office, Finance Office, Personnel Office and Supply Office. The Program Heads, located at Institute facilities on Montreal Road and at the Uplands site, each have support staff so that administrative functions can be conducted at the Program level. Monthly meetings attended by the members of the Management Team and Officers of the Administration Group provide a forum for strategic planning and operations discussions, supplementing the day-to-day interactions between the Program staff, the Institute central management, and the Institute support staff. The Administration group comprises:

Business Office:

(a) negotiation and documentation of "Agreements" related to the provision of services to the private sector.
(b) protection and exploitation of intellectual property.
(c) assistance to Institute management.
(d) coordination of computerized Institute management information systems.

Information Office:

(a) provision of communications function both external and internal to the Institute.
(b) provision of editorial services related to Institute technical reports.
(c) provision of a Public Relations and Information services.
(d) provision of Institute Word Processing services including maintenance of various databases to support business functions.

Finance Office:

(a) provision of centralized functions for the utilization and monitoring of financial resources for the R&D Programs.
(b) development and preparation of Institute's ongoing financial status along with interpretive advice to the IME management team.
(c) monitoring and accounting of the Institute's contracting-in and joint venture activities which support the business functions of the Institute.
(d) maintenance and regulation of the Institute's Administrative Program financial accounts.

Personnel Office:

(a) coordination of the Institute's activities with respect to Human Resources Management.
(b) advise Institute Managers and staff on NRC and Treasury Board Policies and Procedures with respect to personnel matters.
(c) liaise with NRC Human Resources Branch.

Supply Office:

(a) a central function for purchasing and receiving of goods.
(b) a stores operation.
(c) control of the Institute inventory and surplus disposal

5.2 Business Activities

R&D activities which involve clients are the result of a distributed marketing effort, with researchers, Program Heads, Institute management, and the Business Office all participating. The Institute also receives support from the Marketing Services Office to expand IME's client base, and from the Intellectual Property Services Office in technology licensing.

IME's newly-formed Business Office created a heightened awareness of the value of intellectual property, and helped make the arrangements negotiated with clients more consistent with NRC policies.

5.3 Human Resources

In addition to the training provided to individuals on staff, usually in response to the Performance Planning and Review (PPR) process, some group sessions were arranged when a common need was identified. The most significant example of the latter initiative was a series of seminars on delivering effective presentations - almost all research and management staff attended. As well, workshops were held for enhancing supervisory skills and computer skills.

The Institute undertook to address NRC's training role in technology fields in several ways. For example, twenty-five co-op and summer students spent their work terms in the various facilities of the Institute, learning theory and practice under the tutelage of world-class researchers. Professional staff seconded to IME, in some cases as part of an exchange, were able to participate in a variety of projects, thus learning while contributing. In all, sixty-one guest workers and visiting researchers were exposed to the R&D activities of IME. The Institute also sponsored Research Associates and Fellows, and the equivalent of thirteen person-years in revenue-supported positions. At the end of their term these staff leave the Institute with all the benefits such experiences can bring.

The first year of operation as an Institute of six R&D Programs (evolved from ten laboratories) involved not only changes in reporting relationships, but also, to varying degrees, the focus of the research of some staff. To a limited degree this change of organizational elements has reduced the multiplicity of R&D areas, although many competencies remain dependent on the presence of one individual. Much work remains to ensure technological back-up and succession among staff, although this will have to be balanced with the objective of increasing the number of term positions for training purposes.

6. Institute Resource Profile

6.1 Financial Resources

Annual Expenditures and Revenue

(Thousands of dollars)	1991-92	1990-91
Expenditures		
Salaries and Employee Benefits	14,024	16,660
Other Operating	2,711	2,830
Capital	3,147	1,927
Total Expenditures	**19,882**	**21,417**
Revenue	**2,246**	**2,101**

Additional Financial Information

(Thousands of dollars)	1991-92
Applicable Corporate Overhead	5,112
Buildings (Historical Cost)	14,204
Equipment (Historical Cost)	42,783
Fully recovered expenditures incurred on behalf of other government departments	2,184

The Institute resource allocations and expenditures for 1991-92 are shown in the following tables.

Resources

Internal Allocations ($000s)		
Salaries (CV 10)[1]	11 452	
Operating (CV 01, 12)	2 516	
Minor Capital (CV 15)	2 372	
Major Capital (CV 21)[2]	745	
Subtotal Internal Allocation		**17 085**
External Allocations ($000s)		
Revenue-based Allocation[3]		
RPY salaries	499	
RPY overhead (30%)	149	
Operating (CV 08)	448	
Capital (CV 17)	305	
Subtotal External Allocation		**1 401**
Financial Arrangements (CV 86)		**2 756**
Collaborators' Contributors to NRC (CV 76)		**225**
Deposit and Trust Account (CV 75)		**99**
Total Resources[1]		**21 566**

[1]Includes WISE Program; excludes employee benefits at 17.74%

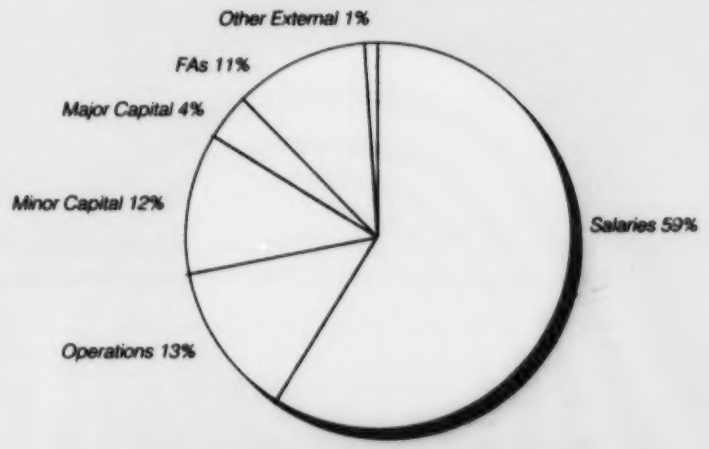
[2]Construction of Wave Research Flume (Coastal Zone Engineering Program)

[3]Only a portion of earned Revenue ($2,246K) is available to the Institute

Expenditures

Expenditures ($000s)		
Salaries (CV 10)	11 418	
Operating (CV 01, 12)	2 288	
Minor Capital (CV 15)	2 115	
Major Capital (CV 21)	735	
Sub-total		**16 556**
Revenue based expenditures		
RPY salaries	499	
RPY overhead	149	
Operating (CV 08)	424	
Capital (CV17)	297	
Sub-total		**1 369**
Financial Arrangements Expenditures (CV 86)		**2 184**
Collaborators' Contributions to NRC (CV 76)		**225**
Deposit and Trust Accounts (CV 75)		**99**
Total Expenditures		**20 433**

These expenditures may be presented in graphical form:



Initial allocations of operations and minor capital funding were bolstered from the Vice-President Engineering reserve in mid-year. Due to the spending freeze imposed by Treasury Board at the end of January only 94% of the total base allocations were expended by the end of fiscal year. For the same reason expenditures from financial arrangements with other government departments amounted to $2.2M. On the other hand revenue exceeded the prediction of $1.8M by over $0.4M.

The human resource distribution and financial expenditures by Program

Program	Staff positions at year end (excluding RPY)	Salaries 91-92 ($000s)	Ops (CV01) ($000s)	Cap (CV15) ($000s)	Revenue (CV 08,17) ($000s)	RPY Positions ($000s)	FA (CV 86) ($000s)
ADM	18	1004	692	58	32	1	0
AMT	43	1802	229	519	0	0	3
CZE	28	1659[2]	349	256	212	2	144
CRE	21	1264	205	351	209	1[1]	779
CFE	39	2062	289	358	414	3	559
GTT	22[1]	1275	215	78	173	3	16
MET	44	2352	309	495	329	5	683
TOTAL	**215[1]**	**11418[2]**	**2288**	**2115**	**1369[3]**	**16[1]**	**2184**

[1] *includes part-time positions*
[2] *excludes benefits of 17.74%*
[3] *includes salary and 30% overhead for staff supported from revenue (RPYs)*

6.2 Human Resources

The Institute Human Resources at the end of 1991-92 are shown below:

Continuing & Non-Continuing Positions

Managers (MGs)	9
Research Officers (ROs)	64
Technical Officers (TOs)	107
Research Council Officers (RCOs)	1
Professional Support (FI, PE, CS, TR, IS, PG, AS)	13
Administrative Support Staff	17 *
Operational Support Staff	4
Positions Supported from NRC Resources	215 *
Positions Supported from Revenue	16 *
Total Staff	**231****

* *includes part-time positions*
** *does not include secondments but does include vacancies*

Non-NRC Staff Complement - Full Time PY Equivalents

	Number of Individuals	PY Equivalents
Guest Workers & Other Visiting Researchers	61	27
Women in Science and Engineering (WISE)	1	0
Summer/Co-op Students	25	9
Research Fellows	1	1
Technical Associates	0	0
NRC/University Co-op Studies	0	0
Other Individuals	0	0
Total Non-NRC Staff Complement	**86**	**36**

The move from PY control to wage envelope control has resulted in more flexibility for staffing actions, however these benefits have not been fully realized due to the increased demand on Human Resources Branch. The positions vacant at year end will be filled as soon as possible in 1992-93.

Training was provided for staff through course attendance, both external and internal, through secondment and through educational leave. A move to fill more positions on a term basis was begun and will accelerate in 1992-93, with the intent that term staff will take their skills to Canadian industry when they terminate their employment with NRC. Management training for the research staff was instituted on a broad basis and will continue in the coming year.

The ratio of technical officers to research officers varies widely from program to program depending on the nature of the program and the facilities that are associated with it. Each Program Head has the flexibility to adjust that ratio as need and opportunity arise.

7. Institute Advisory Board

The Advisory Board for IME was appointed early in 1991 and held its first meeting on 26 April, 1991.

The Terms of Reference which were approved by the Executive Committee of Council are listed below:

Terms of Reference

1. To advise Council and NRC Senior Management on the direction and management of Programs of the Institute;

2. To assist IME management in strategic planning, in setting program priorities and directions, and in developing business plans, which assure IME's continuing relevancy to the needs of Canadian industry, especially those of:

   - industrial sectors of transportation, resource industries and manufacturing.
   - national issues (competitiveness, environment, safety, energy flexibility, national security).
   - sustaining a national base of S&T and highly qualified personnel for the longer term.

3. To review annually the overall performance of the Institute in achieving its objectives;

4. To foster client awareness of the mission and capabilities of the Institute.

On the Board's recommendation, IME prepared a strategic plan for each of the six R&D Programs. These plans, in draft form, were presented to the Board at its second and latest meeting held on 12 November, 1991. It is through these plans that the Board will have a direct input to the research program content. These strategic plans, along with the Institute Annual Plan and Annual Report, will provide a measurement framework by which the Board can assess overall performance. A list of Board members is found in Annex VIII.

Annex I

Research Activities & Priorities

Advanced Manufacturing Technology Program (AMT)

The Advanced Manufacturing Technology (AMT) Program contributes to the mission of IME by bringing together the disciplines of mechanical and manufacturing engineering to foster and undertake the development of manufacturing processes and systems, and the application of advanced technologies and materials in design and manufacturing. The AMT Program also provides specialized Design and Fabrication manufacturing support to R&D projects within NRC Institutes.

Specific achievements in 1991-92 include:

- Initiated a collaborative program to develop laser transformation hardening and cladding techniques. This technique has already identified savings of $2M in the company which addresses a multi-million dollar market.
- Investigated laser surface modification techniques designed to extend the life of CANDU reactors, with potential savings of many millions of dollars. Collaborative program with AECL expected.
- Purchased new 3 kW CO_2 laser and Q-switched diode pumped YAG laser compatible with CNC machines.
- Established process parameters and obtained U.S. patent for electro-mechanical machining and laser precision machining. Laser precision machining of silicon nitride materials developed to point where patent is pending.

The present AMT Program has been designed to complement R&D in other NRC Institutes, since the key to modern manufacturing is the integration of many disciplines, such as information technology, systems, materials and processes, as well as management sciences.

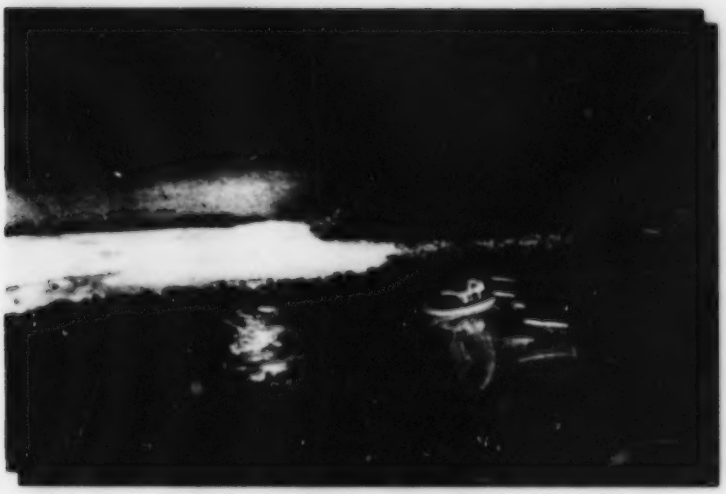
A further important aspect of this manufacturing technology program is "manufacturing support" to other NRC laboratories. Many of these laboratory projects are high risk, in terms of the availability of solid information and of appropriate manufacturing technology, and certainly could not be regarded as candidates for full cost recovery; this demands more precisely defined requirements and the reliance on technology which is available in job shops. A benefit from providing manufacturing support is the insight obtained into potential manufacturing problem areas where manufacturing research is required. For example, the present project on machining of advanced materials resulted from challenges in supporting NRC programs in advanced materials.

The experience gained in this way has placed IME in a strategic position to deal with critical problems now facing some Canadian manufacturers.

Coastal Zone Engineering Program (CZE)

The Coastal Zone Engineering (CZE) Program contributes to the mission of IME by undertaking, supporting and promoting research, development and application of coastal engineering in support of the needs of Canadian industry and government to enhance productivity and competitiveness and to improve Canada's social and economic conditions.

The CZE Program provides leadership for Canadian engineers in developing better understanding of coastal processes such as wave propagation and shoaling, erosion and deposition, wave forces, and the response of coastal structures to waves, currents and winds. Model testing is carried out in large wave basins using the latest wave generation equipment and



Model study of marina for Hawaii. (Photo courtesy of W.F. Baird and Associates Coastal Engineers Ltd.)

control techniques which the Laboratory is constantly improving. NRC-patented technologies on wave generators, wave absorbers, and GEDAP, are licensed to different Canadian companies which are marketing them successfully around the world. The Laboratory provides technical support and continuing collaborative development. Through international cooperation, research activities are augmented by exchange of personnel and software, carrying out projects of common interest and importance, and by acquiring the latest expertise and tools for use by NRC and Canadian coastal engineers. Canadian coastal consultants compete for projects around the world based on access to the facilities and expertise available at NRC. A major effort is underway to acquire and develop hydronumerical models and to verify them by comparison to physical model results.

Specific achievements in 1991-92 include:

- Installed a new $1M Wave Research Flume. This world-class facility is 98m x 2m x 2.7m deep and allows the study of coastal processes at much larger scale factors and Reynolds numbers than previously possible.

- Expanded and supported the transfer of wave generation, control, and analysis technology developed in the CZE Program. Sales of the NRC wave generator technology, through W.R. Davis Engineering Ltd., as well as wave generator control and wave analysis software, through Dominis Engineering Ltd., have resulted in contracts in Canada, Australia, USA, France, Germany, Spain and Korea with a total value of $8M in 1991.

- Increased collaboration with Japanese hydrodynamic research institutes. A six-month secondment of a CZE Research Officer led to a major advance in the theory of wave transformations in coastal zones.

- Undertook physical and numerical modelling of coastal processes and works for the client community. Collaborators included Canadian International Development Agency, Quebec Iron and Titanium, Energy, Mines and Resources, Public Works, Fisheries and Oceans, Ports Canada, W.F. Baird and Associates, Fleet Technology Ltd., Delcan and Sandwell Inc., Canadian universities (Queen's, Toronto, Dalhousie, Memorial, British Columbia) as well as East Anglia and City University, U.K.

- Enhanced hydronumerical modelling capability by arranging a collaborative project on numerical modelling of beach processes with Hydraulics Research Ltd. (UK).

CRE collaborates extensively both nationally and internationally

Cold Regions Engineering Program (CRE)

The Cold Regions Engineering (CRE) Program contributes to the mission of IME by undertaking, supporting and promoting research, development and application of mechanical engineering technology to improve the capabilities and performance of vehicles, thermal systems, structures and other engineering equipment under Canadian climatic conditions and with reduced environmental hazards.

Specific achievements in 1991-92 include:

- Established a tri-partite collaborative agreement with EMR and Sunwell Engineering Ltd. for the study of ice slurries as heat transport fluids for large building cooling systems. Completed a study of the hydraulic and heat transfer properties of the SORENCO supercooled ice slurry.
- Completed a joint study with DuPont Canada Ltd. to quantify the thermo-dynamic performance and long term stability of HCFC-123 refrigerant in a Steam Generating Heat Pump.
- Commissioned a high accuracy facility for the measurement of the viscosity of alternative refrigerants and refrigerant mixtures.
- Accomplished the "first-ever" systematic creep tests on Arctic ice.
- With Gulf Canada, investigated ice load apportioning through grounded ice rubble. Ice rubble mounds, if used as exploration drilling islands, could reduce island construction costs, typically $25M to $75M, by a factor of 4.
- In conjunction with Instrumar Ltd. and the Transportation Development Centre of Transport Canada, conducted an extensive environmental characterization of a sensor for precipitation on the lifting surfaces of aircraft. (This has a total sales potential of $50M.)
- Achieved high rate of client usage of facilities including a major contract for Bombardier to support their $20M sale of urban transit railcars to New York City.

There is extensive external collaboration with the Canadian Coast Guard and international organizations concerned with the effects of ice on transportation and resource industry operations in Arctic waters, including acquisition and analysis of ice field data and developing a collaborative project with Finland on ice/propeller interaction.

Within NRC, the CRE Program Manager has responsibility for co-ordination of all Ice Research involving IME and IMD. Also a CRE researcher serves as Project Leader for the IBM/NRC Joint Study Agreement to evaluate RS/6000 computer systems in solving and displaying results of Computational Fluid Dynamics problems.

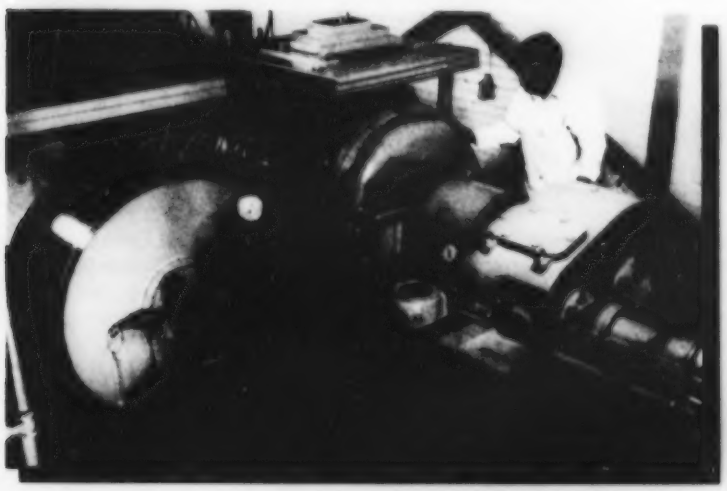
Combustion and Fluids Engineering Program

The Combustion and Fluids Engineering (CFE) Program contributes to the mission of IME by undertaking, supporting, and promoting research and development leading to better understanding and application of combustion and fluid dynamics in two major economic sectors, transportation and resource industries.

Over the past several decades, leading edge technology in the gas turbine field has been responsible for significant advances in the understanding of combustion phenomena and internal flows. The Institute, through a number of national and international linkages continues to contribute to these advances. The research effort is, however, much broader, addressing the larger and increasingly important areas of combustion applications in reciprocating engines and industrial processes. The Program is also aimed at Canadian needs

in fluid dynamics research relevant to transportation and diverse industrial processes including high speed water jet technology. IME expertise and facilities in this Program area related to gas turbines, reciprocating engines and fuels are unmatched elsewhere in Canada.

2 MW Exhauster - a recently refurbished CFE National Facility



Studying Turbulent Flames
A fundamental study to determine the structure and mechanism of the propagation of pre-mixed turbulent flames as related to combustion in spark ignition engines.

Specific achievements during 1991-92 include:

- Determined the influence of sulphur dioxide, fuel-bound sulphur, flame temperature, and inert gas dilution on soot formation rates. This has major implications with regard to emissions and fuel quality regulations in Canada's transportation systems.
- Temperature distributions in highly sooting laminar flames and in turbulent diffusion flames were determined using Coherent Anti-Stokes Raman Spectroscopy (CARS).
- Established collaborative project on liquid spray flow field dynamics with Conamara Ltd. to develop low emission burners using various liquid fuels.
- Recorded images of dense regions of intermittent diesel sprays to improve understanding of combustion processes. Important new features discovered.
- Developed and encoded probability density function (pdf) model for propane jet flame combustion and incorporated into existing computational fluid dynamics code "TURCOM" to improve experimental and computational compatibility.

Ground Transportation Technology Program (GTT)

The Ground Transportation Technology (GTT) Program contributes to the mission of IME by undertaking, supporting and promoting research, development and application of mechanical engineering technology to improve the productivity and safety of railway and highway transportation in Canada.

Specific achievements during 1991-92 include:

- Defined strategic relationship with the Association of American Railroads and initiated collaborative projects in vehicle dynamics modelling and in bearing analysis.
- Commissioned the Wheel, Bearing and Brake Facility, and first tests conducted in collaboration with CP Rail, CN Rail and Transport Canada.
- Completed the most comprehensive package of performance measures so far developed for assessing highway truck stability and control (in collaboration with a visiting researcher from DSIR (Department of Scientific and Industrial Research), New Zealand.)
- Defined the IME/GTT contribution to the OECD (Organization for Economic Cooperation and Development), 14-country program on heavy truck vertical suspension dynamics and pavement damage. Completed a major review of all applicable vertical dynamics theories. Launched the experimental portion of the study to determine the spatial repeatability of peak vertical dynamic loads.
- Maintained and operated National Facilities to benefit client community, including major compression test of prototype urban transit railcar for Bombardier in support of $20M sale to New York City.

Machinery and Engine Technology Program (MET)

The Machinery and Engine Technology (MET) Program contributes to the mission of IME by undertaking, supporting and promoting research, development and application of mechanical engineering technology to enhance the design, operation and maintenance of machinery and engines.

Specific achievements during 1991-92 include:

- Undertook collaborative ground level testing of Real Time Thrust Sensor (RTTS) on F404 Engine with Canadian and Australian participation. (Canadian sales potential of RTTS estimated at $35M.)
- Completed control system fault study on J85 afterburning turbojet and quantified engine performance changes to assist validation of fault diagnosis and prognosis.
- Developed and transferred Instantaneous Crankshaft Angular Velocity (ICAV) measurement and interpretation techniques for diesel engine condition monitoring.
- Developed novel techniques for detection of incipient and advanced gear tooth faults developed using data from collaborative project with Pratt & Whitney Canada.
- Improved techniques for sound intensity measurement in difficult industrial situations where conventional methods fail.

- Apply rolling contact tribology expertise to industrial problems, e.g., by solving a railcar wheel shelling (fatigue) problem for Quebec Cartier Mining (costing $500K/annum) diagnosed as due to use of incorrect new wheel profile.

- Development and use rotor dynamics and balancing expertise to solve MacMillan Bloedel apparent imbalance problem through diagnosis as bearing misalignment (increased productivity of $2.5 M/annum for this unit alone).

- In collaboration with Paprican a study of the wear of special alloys for use in pulp mills was undertaken. It was shown that for certain applications, currently used materials are as good as some new but more expensive alloys.

- Further experiments with brake materials in a high vacuum environment have led to further elucidation of the important effect played by interfacial debris between conforming sliding surfaces.

- Demonstrated experimentally for Kingsbury Bearings that a leading edge groove reduces the power losses and the operating temperature of tilting bad journal bearings.

Annex II

Publications

The attached is a listing of the IME Technical reports written during this fiscal year. Controlled and classified reports (8) do not appear on the list. Laboratory Memoranda (6), and Calibration Analysis and Test Reports (45), which represent preliminary information or minor laboratory projects respectively, are also excluded.

Refereed journal articles are also listed below.

Advanced Manufacturing Technology Program

Bande, H., Esperance, G.L., Islam, M.U., Koul, A.K. *1991. Laser Surface Hardening of AISI 01 Tool Steel and its Microstructure. Journal of Material Science and Technology, May, Vol. 7, pp. 452 - 457. Refereed. IME-AMT-JRL-001*

Combustion and Fluids Engineering Program

IME-CFE-TR-001
Lai, M.K.Y. *1992. Calculation of Turbulent Reactive Flows in General Orthogonal Coordinates. Institute for Mechanical Engineering, National Research Council, 40 pp. (NRC No. 32128).*

Vijay, M.M. *1992. Comparison of the Performance of High-Speed Abrasive-Entrained Cavitating and Plain Water Jets for Selective Mining Applications. International Journal of Surface Mining and Reclamation, Vol. 6, pp. 1 - 9. IME-CFE-JRL-009*

Vijay, M.M., *Grattan-Bellow, P.E. 1991. The Influence of Properties of Rocks on Nozzle Design for Drilling and Slotting with Water Jets. International Journal of Water Jet Technology, Vol. 1, No. 3, pp. 117 - 133. IME-CFE-JRL-008*

Szymczak, M., *Tavoularis, S., Fahim, A., Vijay, M.M. 1991. Flow Visualization of Cavitating, High-Speed, Submerged Water Jets. Trans. of the ASME, Journal of Engineering for Industry, Vol. 113, pp. 485 - 489. IME-CFE-JRL-007*

Gulder, O.L., Snelling, D.R. *1991. Formation and Temperature of Soot Particles in Laminar Diffusion Flames with Elevated Temperatures. 23rd Symposium (International) on Combustion, Vol. 23, pp. 1509 - 1516. IME-CFE-JRL-006*

Gulder, O.L. *1991. Turbulent Premixed Combustion Modelling Using Fractal Geometry. 23rd Symposium (International) on Combustion, Vol. 23, pp. 835 - 842. IME-CFE-JRL-005*

Gulder, O.L. *1991. Turbulent Premix Flame Propagation Models for Different Combustion Regimes. 23rd Symposium (International) on Combustion, Vol. 23, pp. 743 - 750. IME-CFE-JRL-004*

Gulder, O.L., *Glavincevski, B. 1991. Influence of Fuel-Bound Sulfur on Soot Formation in Laminar Diffusion Flames of Liquid Hydrocarbons. Combustion and Science Technology, Vol. 77, pp. 337 - 343. IME-CFE-JRL-003*

Gulder, O.L. *1992. Soot Formation in Laminar Diffusion Flames at Elevated Temperatures. Combustion and Flame, Vol. 88, pp. 74 - 82. IME-CFE-JRL-002*

Carscallen, W.E., Oosthuizen, P.H., Arthur, F.J. *1991. An Experimental Evaluation of a Method of Using Localized Laser Heating in the Determination of Wall Shear Stress. Application of Laser Techniques to Fluid Mechanics, Springer-Verlag. IME-CFE-JRL-001*

Cold Regions Engineering Program

IME-CRE-TR-003
Oleskiw, M.M. *1991. Freezing Precipitation on Lifting Surfaces. Institute for Mechanical Engineering, National Research Council, 37 pp. (NRC No. 32124)*

IME-CRE-TR-002
Sayed, M., Frederking, R.M.W. *1991. A Review of Ice Force Measurements on Light Piers in the St. Lawrence River and Great Lakes. Institute for Mechanical Engineering, National Research Council, 27 pp. (NRC No. 32126)*

IME-CRE-TR-001
Timco, G.W., Frederking, R.M.W. *1991. Impact Tests on Freshwater Ice. Institute for Mechanical Engineering, National Research Council, 388 pp. (NRC No. 32121)*

Frederking, R.M.W., Sayed, M., Penney, G. *1992. Ice Forces on Light Piers in the St. Lawrence Seaway. International Journal of Offshore and Polar Engineering, Vol. 2, No. 1, pp. 67 - 72. (NRC No. 33564) Refereed. IME-CRE-JRL-003*

Frederking, R.M.W., Sayed, M. *1992. Ice Impact Force Measurements on a Vertically Faced Bridge Pier. ASME Journal of Offshore Mechanics and Arctic Engineering, Vol. 114, No. 1, pp. 63 - 65. (NRC No. 33563) Refereed. IME-CRE-JRL-002*

Badaye, M., Gupta, R.P. 1991. Investigation of the Dynamics of a Magnetically Induced Compression Gas Puff. IEEE Transaction on Plasma Science, Vol. 19, No. 5, pp. 872 - 878. (NRC No. 33544) Refereed IME-CRE-JRL-001

Coastal Zone Engineering Program

IME-CZE-TR-005
Faure, T.D. 1992. Numerical Modelling of Wave Reflection from Upright Variable Porosity Wave Absorbers. Institute for Mechanical Engineering, National Research Council, 58 pp. (NRC No. 33565)

IME-CZE-TR-004
Cornett, A.M. 1991. Crossing Wave Forces on a Rigid Segmented Column. Institute for Mechanical Engineering, National Research Council, 98 pp. (NRC No. 32125)

IME-CZE-TR-003
Funke, E. 1991. A Seal for Model Testing of Offshore Structures. Institute for Mechanical Engineering, National Research Council, 16 pp. (NRC No. 32122)

IME-CZE-TR-001
Ibbott, P., Whittington, M. 1991. Valuation of Shoreline Expenditure in Canada. Institute for Mechanical Engineering, National Research Council, 56 pp. (NRC No. 32117)

Willis, D.H. 1991. Improving Shore Protection Design, by J.W. Kamphuis. Discussion. Canadian Journal of Civil Engineering, Vol. 18, No. 5, pp. 890 - 891. Refereed. IME-CZE-JRL-003

Miles, M.D., Mansard, E.P.D. 1991. Comparison of Wave Steepness Based on Spatial and Temporal Distributions. Journal of Hydraulics Research, International Association for Hydraulics Research, Vol. 29, No. 6, pp. 771 - 788. IME-CZE-JRL-002

Cornett, A., Miles, M.D. 1991. Simulation of Hurricane Seas in a Multidirectional Wave Basin. ASME Journal of Offshore Mechanics and Arctic Engineering. Refereed. IME-CZE-JRL-001

Ground Transportation Technology Program

Woodrooffe, J.H.F. 1991. The Science of Trucks. Canadian Society of Mechanical Engineers. Bulletin SCGM, June 1991, pp. 4 - 11. IME-GTT-JRL-001

Machinery and Engine Technology Program

IME-MET-TR-005
Craggs, A., Kim, P.Y., Rogers, R.J., Moore, T.N. 1992. Transcript of Workshop on Machinery Health Monitoring. Institute for Mechanical Engineering, National Research Council, 69 pp. (NRC No. 33557)

IME-MET-TR-004
Hawthorne, H.M., Yick, S.K. 1991. The Wear and Failure Analysis of De-Limber/De-Barker Flail Chains. Institute for Mechanical Engineering, National Research Council, 15 pp. (NRC No. 32119)

IME-MET-TR-003
Messenger, G.S., Thibedeau, R.J. 1991. Performance Comparison of #2 Diesel Fuel and a Tar Sands Derived Diesel Fuel in a Direct Injection Ricardo Hydra Test Engine. Part 2 - Test Data. Institute for Mechanical Engineering, National Research Council, 181 pp. (NRC No. 32115)

IME-MET-TR-002
Messenger, G.S., Thibedeau, R.J. 1991. Performance Comparison of #2 Diesel Fuel and a Tar Sands Derived Diesel Fuel in a Direct Injection Ricardo Hydra Test Engine. Part 1. Institute for Mechanical Engineering, National Research Council, 78 pp. (NRC No. 32114)

IME-MET-TR-001
Chappell, M.S. 1991. Instantaneous Crank Angle Velocity (ICAV) Technology Brief. Institute for Mechanical Engineering, National Research Council, 18 pp. (NRC No. 32111)

Smith, R.E., Kalousek J. 1991. A Design Methodology for Wheel and Rail Profiles for Use on Steered Railway Vehicles. Mechanics and Fatigue in Wheel/Rail Contact, Grassie, S.L. Ed., Elsevier, and WEAR, Vol. 144, pp. 329 - 342. IME-MET-JRL-002

Krishnappa, G., Chiu, V. 1991. Calibration and Performance Verification of Sound Intensity Probes Using Gating Technique. Noise Control Engineering Journal, Vol. 36, No. 3, pp. 137 - 146. Refereed. IME-MET-JRL-001

Annex III

Distinctions Received

Dr. Béatrice Deschamps, a post-doctoral researcher with the Combustion and Fluids Engineering Program has been awarded the prestigious *Prix Paul Lafitte* by the *Groupement Français de Combustion* (The Combustion Institute/ French Section) for her Ph.D. dissertation which she defended in France on 10 December, 1990.

On 24 May, 1991, ***Norman Kallio*** received the *Ontario Association of Certified Engineering Technicians and Technologist "MERIT AWARD"* at their Annual General Meeting Awards Dinner. The award was "to recognize many years of dedicated service to the Association".

Dr. Nirmal Sinha of the Cold Regions Engineering Program was awarded the ASME's *Ten Paper Award* at the *10th International Conference on Offshore Mechanics and Arctic Engineering* on 25 June, 1991, in Stavenger, Norway. This award was established in 1991 to celebrate the 10th anniversary of the Offshore Mechanics and Arctic Engineering (OMAE) Division of the American Society of Mechanical Engineers conferences.

On 13 November, Dr. Pierre O. Perron, NRC's President, hosted an informal reception known as the *"NRC Annual Awards Ceremony"*. This informal reception was to recognize the achievements of staff members who, either individually or collectively, have given particularly meritorious service to NRC during 1990-91. The award categories are the Merit Awards, Patent Awards and Royalty Sharing Incentives. ***Ed Funke*** and ***Mike Miles*** received awards in recognition of the significant royalty payments which NRC has received from the licensing of their segmented wave generator technology. ***Joe Kalousek*** was recognized for the licensing of a high and positive friction lubricant. ***Norm Kallio*** and ***Béatrice Deschamps*** were congratulated on receiving the Ontario Association of Certified Engineering Technicians & Technologist "Merit Award" and the Paul Lafitte Prize as described above. Royalty Sharing Awards were also presented to: ***James Stallabrass, Bill Bailey, Ray Ringer*** and ***Pat Hearty*** for the Helicopter Ice Detector; ***Ray Ringer*** for the Railway Switch Air Curtain; ***Kees Zwarts*** for the Liquid Level Height Transducer; ***Bill Hayes*** and ***Helen Tucker*** for the Low Noise Valves; ***Clive Dayson*** for the Mechanical Yard Logging Carriage; ***Joe Ploeg*** and ***Wayne Jamieson*** for the NRC Progressive Wave Absorber; and to ***Daniel Brunelle*** for the "CNC Servant", a software package for numerical control of machine tools.

Les Gardner (retired) received the Canadian General Standards Board "Certificate of Merit" for his outstanding contributions to the development of standards on behalf of the CGSB.

Paul Stringer (retired) received the Canadian General Standards Board "Certificate of Merit" for his major contributions to the development of test methods.

Awards Presented

The *1991 Student Design Competition of the CSME* (Canadian Society for Mechanical Engineering) was held at the University of Manitoba on 5 June. The *First Prize was awarded by the National Research Council of Canada in recognition of its 75th Anniversary*. Dr. Lowe presented this top honour to the team of ***Glenn Sollitt*** and ***Tom Krikke*** from the University of British Columbia for their project entitled "Pool-Lift for Handicapped".

The Canadian Industrial Laser Association (CILA) held its annual meeting at NRC as part of NRC's 75th Anniversary celebrations. The focus of the meeting was "Lasers in Action". During this meeting the inaugural *Student Innovation Award*, sponsored by *CILA and IME*, was awarded for excellence in laser technology. A laser-engraved plaque was presented to ***Alain Chandonnet*** of Laval University for his work in Annular Thermokeratoplasy which deals with laser reshaping of the cornea to correct myopia.

On 30 October, 1991, Mr. Don Rudnitski presented the annual *Kuhring Prize* to ***Mr. Burhan H. Jama.*** This scholarship is awarded to the best all-round student in the *School of Technology of Algonquin College* having in mind the qualities of breadth and persistence as typified by M.S. Kuhring, the founder of the Engine Laboratory of the Institute.

The *National Award Trophy* is the product of a partnership between the School of Industrial Design of *Carleton University* and NRC. ***Joanna Boothman***, an industrial design student at Carleton, proposed the underlying concept for the award and the Advanced Manufacturing Technology Program completed the design and produced the prototype from Canadian aluminum. This award for "Excellence in Business-Education Partnerships", is sponsored by The Conference Board of Canada and the member companies of Telecom Canada.

Annex IV

Patents and Licences Issued

Records of Invention

***Nicks, John**, Amplitude and Phase Modulation Analysis Technique for Gears. 5 March, 1992.*

***Brown, T.S.** and **Neill, W.S.**, Method of Measuring Performance of Machine Components from Shaft Speed Fluctuations. 30 May, 1991.*

***Cardinal, P., Carscallen, W.E.** and **Ireland, R.**, Exsufflation Machine. 21 June 1991.*

***Dayson, C.**, Deep Soil Loosening Machine. 29 November, 1991.*

Patent Applications

***Vijay, M.M.**, Ultrasonic Device to Generate Cavitating or Pulsed Jets. Patent Coordination Treaty filing for Europe, Australia and Japan. 5 February, 1992.*

***Cardinal, P., Carscallen, W.E.** and **Ireland, R.**, Exsufflation Machine. U.S. patent application 7/832,895. 10 February, 1992.[1]*

***McGregor, G.**, Light Weight Chain Saw Bar. U.S. patent application. March, 1992.*

***Webster, G.W., Neill, W.S., Wintjes, R., Carr, P., Patel, J., and Ehrseman, J.**; Method of Measuring Instantaneous Crank Shaft Velocity of a Rotary Machine. Canadian patent application 2,041,731. 2 May, 1991.[1]*

***McGregor, G.**, Electrolytic Cleaning and Refurbishment of Grinding Wheels. U.S. patent application. December, 1991.*

***Mogridge, G.R.** and **Funke, E.R.R.**, Protective Shield Against Icebergs and Other Floating Objects. Patent Coordination Treaty filing for U.S. and Norway. December, 1991.*

Patents Issued

***Heggie, W.S.** and **Davies, A.S.**, "Mechanical Power Regeneration System", Canadian Patent 1,285,887. 9 July, 1991.*

***McGregor, G.**, Method and Apparatus for Electrolytically Assisting the Mechanical Shaping of a Workpiece. U.S. Patent 5,045,161. 3 September, 1991.*

***McGregor, G, Wells, W.J.**, and **Islam, M.U.**, Rupture Disc Pressure Relief Device. U.S. Patent 5,080,124. 14 January, 1992.[2]*

Licences Issued

Kalousek, J.; Rail Grinding Gauge. Licenced to **Loram Maintenance of Way Ltd.**, Sherwood Park, Alberta.

van den Berg, B.; NC Reprocessor. User licence granted to **Stone Marine Canada Ltée.**, Iberville, Quebec.

Institute for Mechanical Engineering; Tracometer. Licensed to **Tracometer Inc.**, Milton, Ont.

Trade Marks

TOPAC - a computer software program for numerical control of machine tools.

VERIFOIL - a computer software program for measuring airfoil profiles and for evaluation airfoil blade form characteristics.

[1] *First filing*
[2] *First patent*

Annex V

Papers Presented

Advanced Manufacturing Technology Program

McGregor, G. *1991. Developments in Advanced Manufacturing Technology. 1991 Automotive Parts Manufacturers' Association APMA Annual "Forging New Partnerships" Conference & Exhibition, Hamilton, Canada. Refereed. IME-AMT-PAP-002*

van den Berg, B. *1991. Technology: A Tool for Achieving Quality. Quality in Manufacturing Seminar, Oshawa, Canada. Refereed. IME-AMT-PAP-001*

Combustion and Fluids Engineering Program

Vijay, M.M. *1991. Properties and Parameters of Water Jets. Invited Keynote paper at the Geomechanics 91 Conference, September. Hradec, Czechoslovakia. pp. 207 - 222. IME-CFE-PAP-021*

Vijay, M.M. *1991. Comparison of the Performance of High-Speed Abrasive-Entrained Cavitating and Plain Water Jets for Selective Mining Applications. Paper 15. Proceeding of the 6th American Water Jet Conference. Water Jet Technology Association, U.S.A. pp. 195 - 212. IME-CFE-PAP-020*

Vijay, M.M. *1991. The Potential and Paradox of Cavitating Water Jets. Invited Lecture. Workshop on Water Jet Technology. Singapore. IME-CFE-PAP-019*

Vijay, M.M. *1991. The Influence of Properties of rocks on Nozzle Design for Drilling and Slotting with Water Jets. Invited Keynote paper. Proceedings of the 1st Asian Conference on Recent Advances in Jetting Technology. Singapore. pp. 108 - 128. IME-CFE-PAP-018*

Snelling, D.R., Smallwood, G., Campbell, I.G., Parameswaran, T., Sawchuk, R.A., Logan, D. *1991. CARS Temperature Measurements in a Turbulent Gaseous Diffusion Flame. IEA XIII Task Leaders Meeting, San Francisco, U.S.A. IME-CFE-PAP-017*

Snelling, D.R., Campbell, I., Parameswaran, T., Sawchuk, R.A. *1991. CARS Temperature Measurements in A Turbulent Gaseous Diffusion Flame. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-016*

Smallwood, G.J., Snelling D.R. *1991. Use of Two-Colour Particle Image Velocimetry for Velocity Mapping in Spray Combustion. Poster presented at the 1991 Gordon Research Conference on the Physics and Chemistry of Laser Diagnostics in Combustion, Plymouth, U.S.A. IME-CFE-PAP-015*

Smallwood, G.J., Snelling, D.R. *1991. A Two-Colour Technique for Velocity Mapping in Spray Combustion. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-014*

Oosthuizen, P.H., Carscallen, W.E. *1991. A Numerical Investigation of a Method of Using Measurements of the Heat Transfer from a Laser Heated Spot to Determine Wall Shear Stress. Proceedings of the 2nd World Conference on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics, Dubrovnik, Yugoslavia. pp. 345 - 352. IME-CFE-PAP-013*

Lau, J.H. *1991. Effect of Soot and Radiation in Liquid Fuel Combustion Spring Technical Meeting. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-012*

Lai, M.K.Y., Vijay, M.M., Zou, C. *1991. Computational Fluid Dynamics Analysis of Submerged Cavitating Water Jets. Paper 31. Proceedings of the 6th American Water Jet Conference. Water Jet Technology Association (USA). pp. 411 - 426. IME-CFE-PAP-011*

Lai, M.K.Y. *1991. Modeling of Sulphur Plant Reaction Furnace. 4th International Conference on Numerical Combustion, St. Petersburg Beach, U.S.A. IME-CFE-PAP-010*

Gulder, O.L., Smallwood, G.J., Snelling, D.R. *1991. Interrogation of the Diesel Spray Structure by Laser Tomography and Diffraction. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-009*

Gulder, O.L., M.F. Baksh. *1991. Soot Formation in Laminar Diffusion Flames at Elevated Temperatures. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-008*

Gulder, O.L. *1991. A Turbulent Premixed Flame Propagation Model for the Wrinkled Flame Regime. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-007*

Gulder, O.L. *1991. Influence of SO_2 on Soot Formation in Diffusion Flames. Proceedings of the 13th Task Leaders Meeting, IEA Working Party on Conservation in Combustion, pp. 208 - 210. IME-CFE-PAP-006*

Gulder, O.L., Baksh, M.F. *1991. Soot Formation in Diffusion Flames at Elevated Temperatures. Proceedings of the 13th Task Leaders Meeting, IEA Working Party on Conservation in Combustion, pp. 204 - 207. IME-CFE-PAP-005*

Gulder, O.L., Smallwood, G.J., Snelling, D.R. *1991. Structure of Dense Diesel Sprays. Proceedings of the 13th Task Leaders Meeting, IEA Working Party on Conservation in Combustion, pp. 137 - 141. IME-CFE-PAP-004*

Gulder, O.L., Baksh, M.F. *1991. Soot Formation in Laminar Diffusion Flames of Elevated Temperatures, presented at the 13th International Colloquium on Dynamics of Explosions and Reactive Systems, Nagoya, Japan. IME-CFE-PAP-003*

Gulder, O.L., Smallwood, G.J., Snelling, D.R. *1992. Diesel Spray Structure Investigation by Laser Diffraction and Sheet Illumination, SAE Paper 920577. International Congress and Exposition. 24-28 February, Detroit, U.S.A. pp. 1 - 8. IME-CFE-PAP-002*

D'Souza, M.V., Lau, J.H. *1991. Experiments and Prediction of Liquid Sprays into a Stagnant Atmosphere. 1991 Spring Technical Meeting of The Combustion Institute, Canadian Section, May, Ottawa, Ontario. IME-CFE-PAP-001*

Cold Regions Engineering Program

Coveney, D.B. *1991. Evaluation of Equipment for Use in Cold Regions, 3rd International Symposium on Cold Region Development (ISCORD 91), Edmonton, Canada. IME-CRE-PAP-023*

Timco, G.W. *1991. The Vertical Pressure Distribution on Structures Subjected to Rubble-Forming Ice. Proceedings of the 11th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC'91), September, St. John's, Canada, pp. 185 - 197. Refereed. IME-CRE-PAP-022*

Sinha, N.K. *1991. In Situ Multi-Year Sea Ice Strength Using NRCC Borehole Indentor. Proceedings of the 10th International Conference on Offshore Mechanics and Arctic Engineering, June, Stavanger, Norway, pp. 229 - 236. (NRC No. 32096) Refereed. IME-CRE-PAP-021*

Sinha, N.K., Zhan, C., Evgin, E. *1991. Creep of Sea Ice. Proceedings of the 11th International Conference on Offshore Mechanics and Arctic Engineering (OMAE/ASME), 12-17 June, Calgary, Canada, pp. 261 - 266. (NRC No. 33573) Refereed. IME-CRE-PAP-020*

Meaney, R., Kenny, S., Sinha, N.K. *1991. Medium-Scale Ice-Structure Interaction: Failure Zone Characterization. Proceedings of the 11th International Conference on Port and Ocean Engineering Under Arctic Conditions (POAC-1991), 24-28 September, St. John's, Canada, pp. 126 - 140. (NRC No. 33571) Refereed. IME-CRE-PAP-019*

Derradji-Aoust, A., Sinha, N.K., Evgin, E. *1991. Deformation of a Floating Drilling Platform Made of Built-up Ice. Proceedings of the 10th International Conference on Offshore Mechanics and Arctic Engineering (OMAE/ASME), 23-29 June, Stagenger, Norway, pp. 1 - 8. (NRC No. 33570) Refereed. IME-CRE-PAP-018*

Gagnon, R.E., Sinha, N.K. *1991. Energy Dissipation Through Melting in Large Scale Indentation Experiments on Multi-Year Sea Ice. Proceedings of the 10th International Conference on Offshore Mechanics and Arctic Engineering (OMAE/ASME), 23-29 June, Stagenger, Norway, pp. 157 - 161. (NRC No. 33568) Refereed. IME-CRE-PAP-017*

Linton, J.W., Smale, J.G. *1991. A Steam Generating Heat Pump Using HCFC-123. XVIIIth International Congress of Refrigeration, 10-17 August, Paper 265, Montreal, Canada, pp. 1001 - 1005. (NRC No. 33547) Refereed. IME-CRE-PAP-016*

Timco, G.W., Frederking, R.M.W. *1991. Seasonal Compressive Strength of Beaufort Sea Ice Sheets. Ice Structure Interaction, Proceedings of the IUTAM-IAHR Symposium, September, St. John's, Canada, pp. 267 - 282. (NRC No. 33545) Refereed. IME-CRE-PAP-015*

Frederking, R.M.W., Sayed, M., Penney, G. *1991. Measurement of Ice Forces on Light Piers in the St. Lawrence Seaway. First (1991) International Offshore and Polar Engineering Conference, Heriot-Watt University, Edinburgh, United Kingdom, pp. 499 - 504. (NRC No. 32127) Refereed. IME-CRE-PAP-014*

Linton, J.W., Snelson, W.K., Hearty, P.F. *1992. Effect of Condenser Liquid Subcooling on System Performance for Refrigerants CRC-12, HRC-134a, and HRC-152a. ASHRAE Transactions Volume 98, Part 1, Winter Meeting, January 1992, Anaheim, U.S.A., pp. 160 - 166. Refereed. IME-CRE-PAP-013*

Linton, J.W., Snelson, W.K. *1991. A New Environmentally Acceptable High Temperature Heat Pump. Electric Power Research Institute Conference, Proceedings of the Fourth Meeting "Customers Needs with Heat Pumps" - Invited Paper, 15-18 October, Dallas, U.S.A. Not Refereed. IME-CRE-PAP-012*

Snelson, W.K., Linton, J.W., Hearty, P.F. *1991. Thermodynamic Cycle Performance Comparison Tests of HFC-152a and HFC-134a with CFC-12. XVIIIth International Congress of Refrigeration, 10-17 August, Paper 108, Montreal, Canada, pp. 605 - 610. (NRC No. 33548) Refereed. IME-CRE-PAP-011*

Sicars, S., Hesse, U., Snelson, W.K. *1991. A New Falling Ball Viscometer for Measurement of the Viscosity of Pure Refrigerants and Mixtures. Proceedings of the XVIIIth International Congress of Refrigeration, 10-17 August, Montreal, Canada, pp. 419 - 422. (NRC No. 33558) Refereed. IME-CRE-PAP-010*

Goldstein, V., Gupta, R.P., Wiggin, M., Bellamy, J. *1991. Ice Slurries of District Cooling: An Opportunity for Cost-Effective Cooling and Load Management. Proceedings of the International Symposium on Fluids for District Heating, 10-11 April, Copenhagen, Denmark, pp. 169 - 179. (NRC No. 33551) Refereed. IME-CRE-PAP-009*

Gupta, R.P. *1991. Test of A Friction Additive for Ice Slurry Flows. ASME - JSME Symposium on Turbulence Modification in Multiphase Flows, 23-27 June, Portland, U.S.A. (NRC No. 33555) Refereed. IME-CRE-PAP-008*

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Coastal Zone Engineering Program

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Mansard, E.P.D., Funke, E.R. *1991. A Simplified Method for Computing Non-Linear Celerities. Proceedings of the XXIV International Association for Hydraulic Research (IAHR) Biennial Congress, Madrid, Spain, 9-13 September, pp. B-213 - B-219. Refereed. IME-CZE-PAP-003*

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Ground Transporation Technology Program

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Machinery and Engine Technology Program

Bachinsky, G.S., Kalousek, J. 1991. The Edmonton LRT Rail/Wheel Profile Study. Advanced Rail Management (Consulting Company), ARM-TR02. Report done for Edmonton Transit. 12 September. IME-MET-PAP-010

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Annex VI

Participation on Committees

Administration

Dr. I.R.G. Lowe
- Senior Vice-President, Canadian Society for Mechanical Engineering;
- Member, Canadian National Committee International Union of Theoretical and Applied Mechanics
- Member, Railway Research Advisory Board

Dr. R.G. Williamson
- Canadian Delegate, International Society for Air Breathing Engines;
- Canadian Coordinator, Field of Propulsion, Commonwealth Advisory Aeronautical Research Council

Advanced Manufacturing Technology

Mr. G.R. Campbell
- Canadian Standards Association (CSA), W117.2 M87 Subcommittee, "Safety in Welding, Cutting and Applied Processes", Section 7.1 and 7.2.

Mr. G. McGregor
- Board of Directors, Canadian Industrial Laser Association

Coastal Zone Engineering

Dr. V. Barthel
- Executive Director, Computational Fluid Dynamics Research Society
- Member, Working Group on Moored Ships, Permanent International Association of Navigation Congress

Mr. M.H. Davies
- Secretary, Treasurer and Director, Canadian Coastal Science & Engineering Association

Mr. T.D. Faure
- Member, Energy, Mines & Resources (CANMET) Hydraulics Program Committee

Dr. E.P.D. Mansard
- Canadian Representative in the International Working Group on Extreme Wave Statistics
- Canadian Representative in the Maritime Section of the International Association for Hydraulics Research
- Representative of the National Research Council on the Canadian National Committee for the Engineering Committee on Oceanic Resources
- Coordinator of France-Canada Scientific cooperation in Sedimentary Hydrodynamics
- Coordinator of Japan-Canada Scientific Cooperation in Coastal Engineering

Dr. B.D. Pratte
- Member, Energy, Mines & Resources, PERD Program Committee 6.2 - Marine Engineering
- Member, Energy, Mines & Resources (CANMET), Hydraulics Program Committee

Mr. D.H. Willis
- Member, Executive Committee, Hydrotechnical Division, Canadian Society for Civil Engineering

Cold Regions Engineering Program

Dr. R.M.W. Frederking
- Committee of Ice Experts, Northumberland Strait Crossing Project;
- Interdepartmental Committee on International Science and Technology Relations - Cold Regions
- Member, Energy, Mines & Resources, PERD Program Committee 6.2 - Marine Engineering
- Member, CSA Technical Committee on General Requirements, Design Criteria, the Environment, and Loads (S471)
- Editor-in-Chief of the Journal "Cold Regions Science and Technology"

Dr. R.P. Gupta

- Member, International Energy Agency (IEA) Advanced Fluids Group

Mr. J.W. Linton

- Corresponding Member of American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Technical Committee 9.4
- Canadian Coordinator for International Energy Agency (IEA) Annex 18, "Thermophysical Properties of the Environmentally Acceptable Refrigerants"
- Canadian Coordinator for International Energy Agency (IEA) Annex 21, "Global Environmental Benefits of Industrial Heat Pumps"

Dr. M.M. Oleskiw

- Chairman of Society of Automotive Engineers (SAE) AC-9C, Panel on Atmospheric Icing Characterization
- Member, Scientific Advisory Committee for Instrumar Wind Icing Detector Development for TDC, Transport Canada
- Member, Society of Automotive Engineers (SAE) AC-9C Aircraft Icing Technology Subcommittee
- Member, Society of Automotive Engineers (SAE) AC-9C-90-1 Panel on Icing Facility Characterization
- Member, Icing Technology Activity, Propulsion and Integration Testing and Evacuation. Annex to US-Canada Master Data Exchange Agreement

Dr. M.S. Sayed

- Member, IAHR Working Group on Ice Forces

Dr. N.K. Sinha

- Member of Executive Committee on Constitutive Equations Committee of ASME
- Member of RILEM (International Union of Testing and Research Laboratories for Materials and Structures) Technical Committee, "Ice and Construction"
- Member, Executive Committee of OMAE (Offshore Mechanics and Arctic Engineering) Division of ASME
- Coordinator of Arctic/Polar Symposium of 11th Conference of OMAE, June 7-12, 1992, Calgary, Canada

Mr. W.K. Snelson

- Vice-Chairman and Canadian Delegate on Executive Committee of International Energy Agency (IEA) Advanced Heat Pumps Implementing Agreement
- Member of International Energy Agency (IEA) HEAT Pump Centre, Canadian National Team
- Member of PERD Program Committee 1.2 - Industry
- Member of PERD Program Committee 1.7 - Energy Systems

Dr. G.W. Timco

- Canadian Representative, International Association for Hydraulic Research (IAHR) Committee on Ice Problems
- Chairman, IAHR Working Group on Ice Modelling Materials
- Member, IAHR Working Group on Ice Forces
- Member, American Towing Tank Conference (ATTC) Committee on Ice Testing

Combustion and Fluids Engineering Program

Dr. W.E. Carscallen

- Associate Member of the Heat Transfer Laboratory, Queen's University, Department of Mechanical Engineering.
- Member, Organizing Committee and Session Chairman for the 1992 CAN-CAM Conference

Dr. O.L. Gulder

- Chairman, Combustion Institute, Canadian Section;
- Member of Board of Directors, Institute for Liquid Atomization and Spray Systems;
- Canadian Member of the Executive Committee on Energy Conservation in Combustion, International Energy Agency;

- Member of the Editorial Board, Journal of Atomization and Sprays;
- Committee Member of PERD 1.5 and PERD 5.5;
- Scientific Advisor to Canadian Space Agency on Microgravity Combustion

Dr. M.M. Vijay
- Founder & President: International Society of Water Jet Technology;
- Founder & Editor: International Journal of Water Jet Technology;
- Vice-President, Water Jet Technology Association (USA)
- Chairman of the Board: US Water Jet Technology Association

Ground Transportation Technology Program

Mr. J. Coleman
- Chairman, Transportation Association of Canada's Heavy Vehicle Research Coordinating Committee;
- Member, Transportation Association of Canada's Research and Development Council;
- Chairman, Train Dynamics and Lading Damage Committee
- Alternate NRC member, Railway Research Advisory Board
- Member, Association of American Railroads Implementation Officers Committee

Dr. R.V. Dukkipati
- Member, Editorial Board, International Association for Vehicle System Dynamics

Dr. M. El-Gindy
- Member, Transportation Development Corporation (TDC) Steering Committee, Concordia Expert System Project
- Member of the TDC Steering Committee on the "Development of an Expert System for Analysis of Vehicle Dynamics".
- Advisory Panel Member for the Society of Automotive Engineers (SAE) Safety TOPTEC (Topical Technical Workshop) series.
- Member of the Vehicle Design Committee of the American Society of Mechanical Engineering (ASME), U.S.A.
- Chairman of ASME Session (112th ASME Winter Annual Meeting).
- Coordinator of the ASME Advanced Automotive Technologies Symposium (113th ASME Winter Annual Meeting).
- Member of the Technical Program Committee, Canadian Society for Mechanical Engineering (CSME) FORUM '92.

Mr. M. Serrer
- Past chairman, BYTLUG, Digital Equipment Computer User Society
- Founder, OASGIUG, Ottawa Area Silicon Graphics Inc. User Group
- Member, Digital Equipment Corporation Customer Advisory Board for RISC/ULTRIX

Ms. H.G. Tucker
- Member, Train Dynamics and Lading Damage Committee

Mr. J.H.F. Woodrooffe
- Member, Transportation Association of Canada, Heavy Vehicle Research Coordinating Committee;
- Member, Office for Economic Cooperation and Development (OECD) IR2 Scientific Experts Working Group on Highway Suspensions;
- Member, Office for Economic Cooperation and Development (OECD) IR2 Editorial Subcommittee;
- Member, Transportation Development Corporation, Liquid Slosh Steering Committee;
- Member, Transportation Development Corporation, Anti-Jackknife Device Steering Committee;
- Member, Transportation Association of Canada, Heavy Vehicle Research Co-ordination Committee;
- Member, Transportation Association of Canada, C-Dolly Steering Committee;
- Member, Transport Canada, Advisory Committee for the Study into Motor Vehicle Safety and Productivity Research and Development

Machinery and Engine Technology

Dr. K.R. Brockwell
- Executive Secretary, Associate Committee on Tribology

Dr. P.L. Ko
- Executive Member, British Columbia Section of American Society of Mechanical Engineers (ASME)

Dr. G. Krishnappa
- Member, Technical Committee on Noise, Acoustical Society of America;
- Member, Editorial Advisory Board, Noise Control Engineering Journal, (USA);
- Chairman, International Advisory Board for INTER NOISE 92;
- Member, Scientific Committee for the Second International Congress on Recent Developments in Air & Structure-Borne Sound and Vibration;
- Canadian Focus Officer for TTCP Technical Panel HTP-7 Helicopter Drive Train Monitoring and Engine Vibration Analysis;
- Canadian Representative, International Electrotechnical Commission IEC/TC 29/WG 11 Instruments for the Measurement of Sound Intensity;
- Canadian Representative, International Standards Organization (ISO)/TC 43/ WG 25 Determination of Sound Power Using Sound Intensity Measurements;
- Chairman, American National Standards Institute (ANSI) S1-12 Instruments to Measure Sound Intensity;
- Member, S12-21 Determination of Sound Power Using Sound Intensity.

Mr. J.D. MacLeod
- Member, Society of Automotive Engineers (SAE) EG-1E Gas Turbine Engine Test Facilities and Equipment Committee

Mr. D.M. Rudnitski
- NATO (North American Treaty Organization) Advisory Group for Aerospace Research and Development (AGARD) Propulsion and Energetics Panel - Panel Member and Canadian Panel Coordinator;
- Chairman, AGARD Working Group 23, Transient Measurements in Gas Turbines;
- Chairman and Canadian National Leader for TTCP Technical Panel 7 - Propulsive and Mechanical Systems, Condition Monitoring and Diagnostics;
- Member, ISTC Program Review Group on Pratt & Whitney R&D Program;
- NRC Staff Officer, Master Data Exchange Agreement (MDEA) Propulsion and Integration Testing and Evaluation.

Dr. U.W. Schaub
- Member, Society of Automotive Engineers (SAE) E33-C Measurement Uncertainty in Gas Turbines;
- Member, Society of Automotive Engineers (SAE) Aerodynamics Cooling Subcommittee

Adjunct Professorships

Coastal Zone Engineering

Dr. E.P.D. Mansard
Department of Civil Engineering
Université Laval

Cold Regions Engineering

Dr. R.M.W. Frederking
Memorial University

Dr. R.P. Gupta
Department of Electrical Engineering
McGill University

Dr. N.K. Sinha
Faculty of Engineering
University of Ottawa

Dr. G.W. Timco
Memorial University

Combustion and Fluids Engineering

Dr. M.M. Vijay
Colorado School of Mines

Ground Transportation Technology

Dr. R.V. Dukkipati
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Dr. K.R. Brockwell
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Dr. H.M. Hawthorne
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Mr. J. Kalousek
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University of British Columbia

Dr. P.Y. Kim
Department of Mechanical Engineering
University of British Columbia

Dr. P.L. Ko
Department of Mechanical Engineering
University of British Columbia

Annex VII

List of Employees

Management

Interim Director General
Lowe, Dr. I.R.G.

Director
Chappell, M.S.

Director
Williamson, Dr. R.G.

Program head (Acting) - MET
Chappell, M.S.

Program Head - GTT
Coleman, J.

Program Head - CRE
Frederking, Dr. R.M.W.

Program Head - CFE
Makomaski, Dr. A.H.

Program Head - AMT
McGregor, G.

Program Head - CZE
Pratte, Dr. B.D.

Administration Program

Interim Director General
Lowe, Dr. I.R.G.

Secretary
Charette, M.C.

Directors Office and Business Office

Directors
Chappell, M.S.
Williamson, Dr. R.G.

Secretary
Labrosse, L.L.

Research Council Officers
Smith, S.R.

Management Category
Wallace, Dr. H. (secondment)

Computer Systems Administration
Fougere, J.G.

Finance

Finance Officer
Beaudin, M.R.L.

Finance Clerk
Smith, M.B.A.

Information Services

Information Officer
James, V.M.

Word Processing Operator
Fyffe, J.A.

Personnel

Personnel Officer
Stewart, L.

Personnel Assistant
Vacant

Stores

Supply Officer
Fauteux, B.

Assistant Supply Officer
Sadowski, J.S.

Stores
Campbell, J.-C.
Lanthier, N.
Larry, C.

Advanced Manufacturing Technology Program

Program Head
McGregor, G.
Administrative Assistant
Sarazin, R.G.

Research Officers
Merrett, G.J.
Johnston, D.F.
Islam, M.
Ross, J.E.
van den Berg, B.

Technical Officers
Asboth, I.
Beckinsale, D.G.
Boudreau, D.E.
Campbell, G.R.
Cantin, P.T.
Curran, E.
Dool, W.M.
Evans, F.
Gibson, B.J.
Hajdu, I.
Hussain, M.
Kingston, D.W.
Koczor, R.W.
Kowala, S.J.
Lacelle, G.
Laferrière, R.
Laporte, M.V.
Lebel, J.A.
Macadam, F.A.
Meinert, M.M.
Nichol, P.A.
Quinn, P.D.
Raedisch, W.S.
Rotherham, G.A.
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Waterman, K.A.
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Young, C.

Combustion and Fluids Engineering Program

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Makomaski, Dr. A.H.

Administrative Assistants
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Nadon, M.M.

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D'Souza, Dr. M.V.
Davies, A.S.
Depooter, Dr. K.
Glavincevski, Dr. B.
Gulder, Dr. O.L.
Ireland, R.B.**
Lai, Dr. M.K.Y.
Lau, Dr. J.
Smallwood, G.J.
Snelling, Dr. D.R.
Vijay, Dr. M.M.
Wong, R.

Technical Officers
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Chippior, W.L.
Day, B.J.
Diduch, R.J.
Gareau, D.R.
Gomez, V.
Hunt, P.S.
Kallio, N.N.
Logan, D.L.
McDill, D.E.A.
McMullin, M.A.
Moon, F.G.
Paquette, N.
Perron, E.E.**
Sabourin, R.R.
Sawchuk, R.A.
Smith, R.R.
Turpin, A.
Van den Akker, E.**
Wright, D.R.

Computer Systems Administration
Béland, G.

Cold Regions Engineering Program

Program Head
Frederking, Dr. R.M.W.

Administrative Assistants
Pelley, D.L.*
Vacant

Research Officers
Beale, S.B.
Coveney, D.B.
Gupta, Dr. R.P.
Linton, J.W.
Oleskiw, Dr. M.M.
Sayed, Dr. M.
Sinha, Dr. N.K.
Snelson, W.K.
Timco, Dr. G.W.

Technical Officers
Fraser, C.A.
Hearty, P.F.
Hyde, F.
Jerome, R.
Martin, R.A.
Montreuil, M.A.
Morris, D.E.
Shane, D.F.
Triebe, A.R.**
Vasic, A.Z.*
Wood, G.W.

Operational
Mason, W.G.

Coastal Zone Engineering Program

Program Head
Pratte, Dr. B.D.

Administrative Assistants
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MacDonald, H.

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Barthel, Dr. V.
Cornett, Dr. A.M.
Crookshank, N.L.
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Faure, T.D.
Funke, E.R.R.
Jamieson, W.W.
Laurich, P.H.
Mansard, Dr. E.P.D.
Miles, M.D.
Mogridge, Dr. G.R.
Willis, D.H.

Research Associates
Irani, Dr. M.B.
Nwogu, Dr. O.

Technical Officers
Aitkin, R.B.
Blaney, W.S.
Claes, H.F.M.
Edwards, E.P.
Farnand, J.T.
Girard, R.K.
Gow, W.A.*
Herrmann, C.
Lepage, G.M.
MacDonald, D.

Computer Systems Administration
Pelletier, D.
Wilson, B.C.

Operational
Ryan, J.L.
Wilmore, R.A.

Ground Transportation Technology Program

Program Head
Coleman, J.M.

Administrative Assistants
Jones, J.M.E. (secondment)
Robinson, E.M.*

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Dukkipati, Dr. R.V.
El-Gindy, Dr. M.
Keller, J.
Leblanc, P.A.
Preston-Thomas, J.A.
Tucker, H.G.
Woodroofe, J.
Zwarts, C.M.G.

Technical Officers
Allen, J.H.B.
Brien, W.
Feser, E.F.
James, E.F.
Keller, J.
Koopman, R.
Krzyzanowski, M.
MacLeod, A.
Philippe, R.*
Séguin, Y.
Senn, R.J.
Staudinger, H.J.

Computer Systems Administration
Rennick, R.J.
Serrer, M.
van Blokland, G.

Machinery and Engine Technology Program

Program Head (Acting)
Chappell, M.S.

Administrative Assistants
Cadrin, N.L.
De Ruiter, L.M.*
Vacant

Research Officers
Bird, J.W.
Brockwell, K.R.
Brown, Dr. T.S.
Currie, Dr. T.C.
Dayson, Dr. C.
Dubé, F.R.
Hawthorne, Dr. H.
Kalousek, Dr. J.
Kim, Dr. Y.I.
Ko, Dr. P.L.
Krishnappa, Dr. G.
MacLeod, J.D.
Messenger, G.S.
Rudnitski, D.M.
Schaub, U.W.
Waring, J.C.S.**

Research Associate
Hou, Dr. K.**

Technical Officers
Barry, B.C.
Carvish, J.E.
Chiu, V.J.
Fournier, M.N.
Gerber, C.
Giroux, G.J.
Grabe, W.
Kleinbub, D.
Lam, F.K.
Leung, R.M.
Liko, B.
Matthews, G.
McIntyre, G.
Messenger, G.S.
Moyes, B.W.
Mulligan, M.F.
Nicks, J.E.
Renaud, J.J.
Robertson, M.F.
Rook, H.
Simunek, M.
Smith, J.B.
Thibedeau, R.
Tom, H.W.
Trickett, C.A.**
Vanderhoek, T.P.
Yick, S.E.

****casual employee***
*****limited term staff***

Annex VIII

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